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HANDBOOK

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INVERTEBRATE ZOOLOGY.

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HANDBOOK

OF

INVERTEBRATE ZOOLOGY.

FOR

LABORATORIES AND SEASIDE WORK.

BY

W. K. BROOKS, PH.D.,

ASSOCIATE IN BIOLOGY AND DIRECTOR OF THE CHESAPEAKE ZOOLOGICAL LABORATORY
OF THE JOHNS HOPKINS UNIVERSITY.

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INTRODUCTION.

THIS book is a handbook, not a text-book, and the entire absence of generalization and comparison is not due to indifference to the generalizations of modern philosophical morphology, but rather to a wish to aid beginners to study them.

Most lecturers upon natural science find, no doubt, that preliminary work, the presentation of the facts upon which science is based, absorbs so much time that there is no room for a philosophical discussion of the scientific aspects of the subject.

I have, therefore, attempted to show the student how to acquire a knowledge of the facts for himself, in order to remove this burden from lecturers and text-books.

The types selected for description are necessarily few; but I hope that a thorough study of all the forms which are here described will fit the student for more extensive research.

In the treatment of each type I have not attempted to make an exhaustive monograph for the use of specialists, or to present all that is known about it; but simply to call the attention of the beginner to the structural features which he can readily observe for himself,

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There are many facts of the greatest importance, which the beginner must accept on authority, and as reference to facts of this sort, in an elementary description, for use in the laboratory, could hardly fail to create confusion, such references have been omitted.

The concrete description of specific forms demands figures of the species described, and as it is important that these figures should show nothing that the beginner cannot himself discover in his specimen, the complicated figures which accompany most monographs were found to be impracticable, and most of the cuts have been made for the purpose, by photographic reproduction of the author's drawings, or of drawings made from nature under his direction.

Where it has been thought best to reproduce a figure from a monograph, the author has drawn it with a pen, and this drawing has been photo-electrotyped.

It is hoped that the practicability and significance of the cuts, as guides to dissection and study, will more than compensate for the artistic finish and technical skill which has been lost by the employment of this method of reproduction.

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HANDBOOK

OF

INVERTEBRATE ZOOLOGY.

I. THE STRUCTURE OF AMŒBA.

(*Amœba proteus.*)

AMŒBÆ are frequently to be found in abundance in the superficial ooze which forms a thin layer upon the bottom of nearly every quiet body of fresh water. The ooze may be collected from a pond, stream, or ditch, by gently and slowly skimming the bottom with a tin dipper fastened to a long handle. In gathering the ooze be careful to barely skim the surface, and to avoid disturbing the black mud which usually occurs just below the ooze.

Transfer the material thus gathered to a collecting-bottle, and gather ooze from several bodies of water, preserving each specimen in a separate bottle, for amœbæ may be abundant in one locality and almost absent in another.

Pour the ooze into shallow dishes, such as soup-plates or baking-dishes, putting enough into each dish to form a layer about an eighth of an inch deep over the bottom.

Place the dishes near a window, where they will be well lighted without exposure to the direct rays of the

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sun; fill them with fresh water, and allow them to stand undisturbed for two or three days, in order to allow the amœbæ to creep out of the ooze and accumulate at its surface.

If a permanent supply of amœbæ is desired, each dish may be converted into a small aquarium by the addition of a few floating water-plants, such as "duck-weed," and when covered with a pane of glass, to exclude dust and prevent excessive evaporation, may be kept in good order for several months by simply replacing with fresh water the loss by evaporation.

In a day or two a thin brownish-yellow film will usually be visible over the whole or parts of the surface of the ooze; and portions of this film, almost entirely made up of microscopic organisms which have crept to the surface, may now be examined for amœbæ, in the following manner: —

Compress between the fingers the upper bulb of a medicine-dropper, — a glass tube drawn out to a point at one end, and furnished with a rubber air-chamber at the other, — and then pass the pointed end of the tube into the water close to the surface of the yellow film, and relax the pressure on the bulb. The water will rush into the tube and carry a little of the film with it.

Take the tube out of the water; hold the tip over the centre of a clean glass slide, and, gently compressing the bulb, force a drop or two of the water out of the tube on to the slide.

Cut a strip of writing-paper about a quarter of an inch wide, and, moistening one end of it with water, cut off about a quarter of an inch from the moistened end and lay it upon the slide close to, but not so as to touch, the drop.

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Carefully wipe a thin glass cover, breathe upon it, and, resting one edge of it upon the side of the drop opposite the piece of paper, gently lower the cover on to the paper,

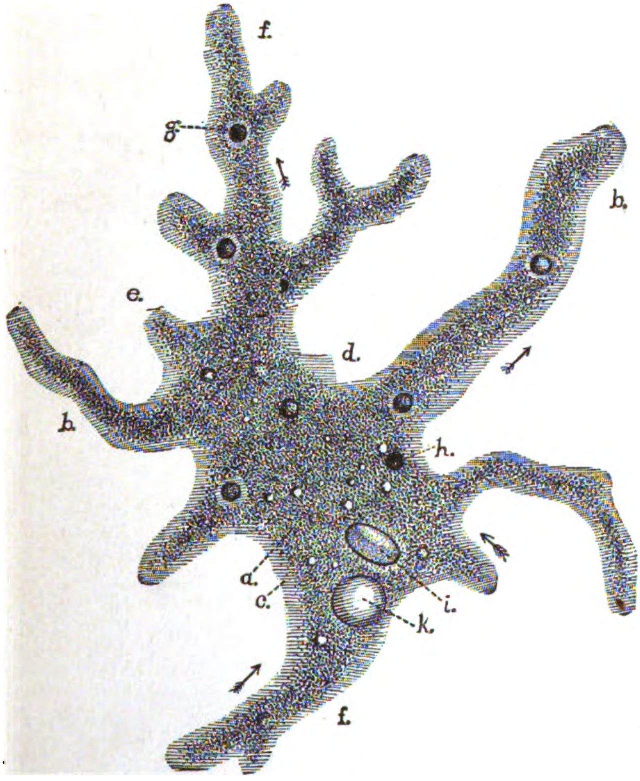

Fig. 1. Amœba proteus, magnified two hundred diameters.
a. Endosarc. *b.* Simple Pseudopodia. *c.* Ectosarc. *d.* First stage in the growth of a Pseudopodium. *e.* Pseudopodium a little older than *d.* *f.* Branched Pseudopodium. *g.* Food vacuole. *h.* Food ball. *i.* Endoplast. *k.* Contractile vesicle.

thus spreading out the drop into a very thin layer. A needle fastened into a handle should be used to lower the cover into place.

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Place the slide upon the stage of the microscope, and examine it with a magnifying power of two hundred or three hundred diameters. If careful examination leads to the discovery of no amœbæ, examine the ooze from another locality in the same way. It is extremely difficult to tell a beginner exactly what to search for. If the student is working under guidance, the instructor should find an amœba, and after the student has had an opportunity to see it he may hunt for others. If working alone, the student should read the following description, and then hunt for an object which agrees with it.

Having found an amœba, note: —

I. The irregular, granular, nearly colorless body, which is made up of an ill-defined central portion (Fig. 1, *a*), and a variable number of irregular processes, the *pseudopodia* (Fig. 1, *b*). The body may be nearly spherical and the pseudopodia small, or the body may be almost absent and the pseudopodia large, and the animal may pass through all the intermediate stages between these two forms in a few minutes, or it may remain without change for several minutes, especially if it has just been transferred to the slide. The very much branched forms, like the one figured, are most common in a drop which has been for some time on the slide undisturbed.

II. The body consists of a pale, nearly colorless, jelly-like substance, the *sarcode*, in which two layers will be recognized.

a. The outer layer or *ectosarc* (Fig. 1, *c*) forms a transparent, very slightly granular film over the entire surface.

b. The darker, more granular *endosarc* fills the interior of the body and extends into the pseudopodia. It contains many bodies, which will be noticed later. There is no abrupt line between the ectosarc and endosarc.

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III. Make a series of sketches of the outline at as short intervals as possible, to show the changes of form.

IV. Study the growth of a pseudopodium. At first it is a simple transparent protrusion (Fig. 1, *d*) of the ectosarc, looking like a drop of fluid which has been squeezed out of the body. As it increases in size, the granular endosarc suddenly rushes into it (Fig. 1, *e*). It may then elongate until it forms a long, blunt, finger-like process, which may remain simple for some time (Fig. 1, *b*), or it may branch (Fig. 1, *f*), by forming new pseudopodia along its sides. Notice that, as the pseudopodium grows, the endosarc flows into it with a well-marked current. In this way the whole body may flow forward into an advancing pseudopodium, which is thus converted into the body of the organism, and may throw out new pseudopodia in the same or in a different direction. Note that, while progressing in this manner, the organism is specialized into: —

a. An anterior progressing region, with numerous growing pseudopodia, and, —

b. A posterior or "following" region, with few pseudopodia. This posterior region frequently has a well-marked, rounded outline covered with small eminences, the last traces of the vanishing pseudopodia. Note that many of the pseudopodia disappear or are withdrawn into the body or into other pseudopodia almost immediately after they become visible.

V. Foreign bodies contained in the endosarc: —

a. The food vacuoles. The endosarc of most specimens will be found to contain small, nearly spherical pellets of food, usually of a yellowish-brown color, although the color varies according to the character of the food. In most cases a clear, transparent space surrounds the

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food ball, and is filled with water which has been swallowed with the food. The ball of food, with its surrounding water, is a *food vacuole* (Fig. 1, *g*). After a time the water disappears, and a number of food balls, without the layer of water, are usually present (Fig. 1, *h*). Sometimes the endosarc contains drops of water without food matter.

b. Occasionally the endosarc contains the entire bodies of small organisms, such as rotifera, algæ, etc., which have been swallowed as food.

c. Occasionally the endosarc contains other foreign bodies, such as grains of sand, particles of sawdust, etc.

d. If possible, watch the process of ingestion of food matter, the formation of a food vacuole, and the expulsion of indigestible matter from the body. Notice that food may pass in or be expelled at any point on the surface.

VI. Structural constituents of the endosarc: —

a. In some specimens the endosarc will be found to contain a discoidal or spherical transparent body, the *endoplast* or *nucleus* (Fig. 1, *i*). It does not change its form with the movements of the body, and it usually lies near the posterior end when the organism is progressing. It may be surrounded by an area of non-granular endosarc.

b. In some specimens a clear, transparent, liquid globule, the *contractile vesicle* (Fig. 1, *k*), may be found, usually behind the nucleus. If carefully watched, it will be seen to gradually enlarge for several seconds and then suddenly collapse and disappear, to reappear again in a few seconds at the same or nearly the same place.

c. The endosarc usually contains other bodies, such as crystals, large granules, and drops of oil.

VII. Make sketches showing as many of these points as possible.

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II. THE STRUCTURE OF PARAMŒCIUM.

(*Paramœcium caudatum.*)

SPECIMENS of the holotrichous infusoria will usually be found in the material which has been collected to obtain amœbæ, and an abundant supply may be procured in the following manner: Fill a small glass beaker or tumbler with water from one of the amœba-aquaria described in the last section. Place a small handful of pieces of hay or dead moss in the water, and allow it to stand in a warm place for about a week. In the winter it may be placed in the direct sunlight, and even in summer the sunlight will not usually be injurious. After a few days a white film will appear upon the surface of the water; and if the lower edge of this film be carefully examined where it touches the glass, great numbers of rapidly-moving white animals, so small as to be barely visible without a lens, will usually be found. When examined with the microscope many or most of these organisms will be found in nearly every case to belong to the species which is here described, but even if this species is not found, almost all the points of the description may be verified in any of the holotrichous infusoria.

Transfer a drop from the surface of the water to a glass slide by means of a dropping-tube, in the way which has been described in Section I. Cover it with a thin glass supported by a small piece of paper or a hair, and examine it with a magnifying power of eighty or one hundred diameters, and notice the oval animals gliding actively across the field of view. Find one whose motions are somewhat restricted by the cover, and, after placing it as

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nearly as possible in the centre of the field, remove the objective from the microscope and replace it by one magnifying two or three hundred diameters.

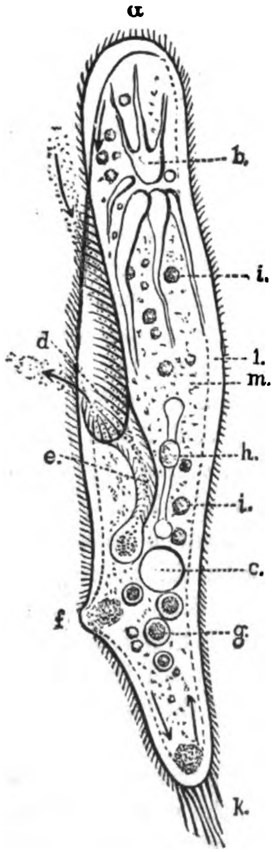

FIG. 2. Paramœcium caudatum. From H. J. Clark, *Mind in Nature*, Fig. 96. Side view; magnified about three hundred diameters.

a. Anterior end. *b*. Contractile vesicle during a period of contraction. *c*. Contractile vesicle during a period of dilation. *d*. The vestibule. *e*. The œsophagus. *f*. The anus. *g*. Food vacuoles. *h*. Nucleus. *i*. Food balls. *k*. Long cilia at the posterior end of body. *l*. Ectosarc. *m*. Endosarc.

Having found the animal again, notice: —

I. The soft, flexible, transparent body (Fig. 2), oval when viewed from above and below, and somewhat slipper-shaped in side view. The posterior end (Fig. 2, *k*) is bluntly pointed, and forms the toe of the slipper, while the anterior end (Fig. 2, *a*) is rounded and somewhat twisted, so that the outline of one side of the anterior end is bent into a shape somewhat like the figure 8. As this side is quite generally uppermost it may be called dorsal.

II. The entire surface of the body is covered with fine hairs or *cilia*, which are in constant vibratory motion. Along the edges of the body they can be seen without difficulty, but upon the surface they are visible only as fine dots. The cilia are of two kinds.

a. The locomotor cilia, which are quite small, and cover nearly the whole of the body. By their vibration the animal is made to move through the water. At the posterior end of the body there is a small tuft of much larger cilia (Fig. 2, *k*).

b. Around the edges of the 8-shaped outline of the anterior end, notice a row of much larger cilia. These give rise to currents by which floating particles of food are carried into the mouth, which is situated on the posterior bend of the 8.

III. The surface of the body is covered by a thin, delicate, transparent cuticle, which is rather difficult to see satisfactorily. The cilia are protruded through holes in the cuticle, and if one of the animals be placed upon a slide in a small uncovered drop of water, and watched as the water evaporates, a good view of the cuticle and its perforations may usually be obtained just at the time when the animal begins to dry.

IV. The body-substance or *sarcode*. The transparent, somewhat granular, body-substance fills the entire space inside the cuticle, and is pretty definitely divided into two layers, which are much more distinct and sharply separated than they are in amœba.

a. The transparent outer layer or ectosarc (Fig. 2, *l*), which lines the cuticle.

b. The much more fluid endosarc (Fig. 2, *m*), which fills the space inside the ectosarc, and is much more granular. It usually contains oil-globules, colored particles, and various foreign bodies which are not found in the ectosarc.

V. Watch a paramœcium push its body into a narrow space between the particles of sediment in the water. Notice that the more fluid endosarc is pushed back by the

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obstruction and accumulates at the posterior end of the body while the ectosarc still follows the outline of the cuticle. After part of the body has been pushed past the obstruction, the endosarc, with the particles which it contains, flows rapidly through the narrow part into the enlargement beyond.

VI. Watch one of the larger particles in the endosarc for some time, and notice that it has a motion which is independent of the changes in the shape of the body. It will be found by very careful examination that the endosarc, with all its contained particles, is slowly circulating around the body, up one side, and down the other, as shown by the arrows in the figure.

VII. The digestive organs. These can be most satisfactorily studied after the animal has been fed with some colored substance, such as powdered carmine or indigo. Place a drop of water, with paramœcia, upon a slide, and mix with the water a little finely-powdered indigo; cover the specimen gently with a cover-glass, and examine with a magnifying power of about two hundred diameters, noticing: —

a. The currents which are caused by the small locomotive cilia.

b. The *peristome* or 8-shaped line of large cilia at the anterior end of the body, by the action of which the carmine is swept into, —

c. The *vestibule*, a widely-open, funnel-shaped chamber (Fig. 2, *d*) lined with cilia, and situated in the posterior bend of the 8.

d. The *œsophagus*, a ciliated tube which runs downwards and backwards (Fig. 2, *e*) into the substance of the endosarc. In this tube the particles of indigo are gradually rolled into a pellet, and from time to time these pel-

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lets are forced, by the contractions of the body, out of the inner end of the tube into the endosarc.

e. One of the pellets, together with a little water swallowed with it, forms a food vacuole, of which several (Fig. 2, *g*) may usually be seen in different parts of the body. A food vacuole is a spherical space filled with water, and containing solid particles of various kinds. As the vacuoles are carried around the body by the circulation of the endosarc, the water and soluble parts are digested out, until at last only the indigestible parts remain embedded in the sarcode as a food ball (Fig. 2, *i*).

f. The *anus.* After a time these particles accumulate at a point (Fig. 2, *f*) upon the dorsal surface about half way between the vestibule and the posterior end of the body. The ectosarc becomes thin over them, and they are then driven out of the body through a temporary anus, the location of which is permanent.

VIII. The *contractile vesicle.* If a specimen which is pretty quiet be carefully watched, a large transparent space will be seen at some point in the body, and after remaining visible for some twenty or thirty seconds, it will suddenly disappear and gradually reappear. In some species there is one near each end of the body (Fig. 2, *b* and *c*), and in others only one, near the middle. When they first appear they are very small; they gradually increase in size until they are quite conspicuous, as shown at *c* in Fig. 2. Radiating channels then make their appearance and extend from the vesicle into the surrounding endosarc. The vesicle now suddenly contracts and disappears, its contents being forced into the tubes, which are visible for a short time longer, as at *b* in Fig. 2, and then gradually disappear also. In a few seconds the vesicle reappears at the same place.

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IX. The *nucleus and nucleolus*. In some species there is one nucleus or endoplast at each end of the body, and in others only one near the middle. They are club-shaped masses (Fig. 2, *h*) of granular protoplasm of a firmer consistency than the surrounding endosarc. They are somewhat difficult to see in the living animal, but they may be made more conspicuous by adding a little acetic acid to the water. Close to the nucleus is a much smaller body, the nucleolus.

X. Make a sketch showing as many of these points as possible.

III. THE STRUCTURE OF VORTICELLA.

Any of the numerous species of Peritrichous Infusoria may be used to verify the following description, since the differences between them are very slight. The Vorticellidæ are abundant in both fresh and salt water; and many specimens will probably be found in the hay infusion, which has been employed to propagate Paramœcia. Good specimens for examination may nearly always be obtained from a small aquarium, which has been well stocked with water-plants and kept for a few weeks in a well-lighted place. A glass gallon-jar makes a very convenient aquarium for this purpose, and it should contain no fishes, newts, or other animals large enough to devour the vorticellas.

Although the individuals are microscopic, they are frequently found, in such an aquarium, in colonies of a sufficient size to be recognized by the eye without difficulty.

If the leaves and stems of the water-plants are carefully examined, *under water*, either with or without a

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hand-lens, some of them may be found to carry minute white flocculent spots or tufts which resemble spots of mould. If one of these tufts be gently touched with a needle or a hair, it will instantly shrink back, until it is reduced to an almost invisible white spot. After the disturbance ceases, it soon expands again to its former size.

Having found one of these tufts, grasp with a pair of forceps the leaf or stem which carries it, and cutting out the piece with a pair of scissors, transfer it to a drop of water upon a glass slide; cover it with a cover-glass, which may be supported by a piece of paper, if necessary, and examine it with a magnifying power of about eighty diameters.

When thus examined, the white tuft will probably prove to be a colony of Vorticellidæ, but it may, perhaps, prove to be a colony of Stentors or even of Rotifera. If the student finds that he is unable to verify the following description, he should ask his instructor to examine his specimen.

Having found a colony of Vorticellidæ, notice: —

I. The bell-shaped bodies of the individuals which compose the colony.

II. The stem which projects from the small end of the body of each animal, and joins it to the others and to the supporting body (see Fig. 3).

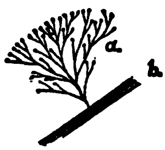

FIG. 3.

FIG. 3. — Diagram of a colony of Vorticellæ, magnified about fifteen diameters.

III. The cilia around the margin of the bell.

IV. Keeping the eye at the microscope, tap the slide gently, or touch the animals with a hair, and notice their rapid contraction.

a. The edge of the bell bends inwards so that the body becomes nearly spherical.

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b. The stem is thrown into a spiral, thus dragging the body back towards the point of attachment.

c. Watch the changes by which the colony gradually expands after the disturbance ceases.

1. The stems straighten.
2. The rims of the bells are slowly everted.
3. The cilia suddenly resume their active motion.

d. Notice the marked contrast between the rapid contraction and the gradual expansion.

V. Make a sketch of the community, showing as many of these points as possible.

VI. Study a portion of the community with a magnifying power of 200 to 500 diameters, and notice: —

a. The body of a single animal: circular when seen from above or below, and bell-shaped in side view, and attached to a stem by its lower or narrow end.

1. The upper edge of the bell is bent out to form a thickened marginal rim, the *peristome*, Fig. 4, *c.*

2. Notice the crown of large cilia carried by the peristome.

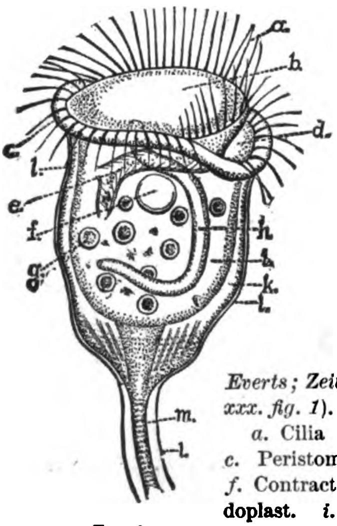

FIG. 4.

FIG. 4. — A single adult, fully expanded individual of Vorticella nebulifera (Ehrb.) magnified about six hundred diameters. (*Slightly altered from Everts. Untersuchungen an Vorticella Nebulifera, von Dr. phil. Eduard Everts; Zeit f. Wiss. Zool. xxiii. 592: 1873. Taf. xxx. fig. 1*).

a. Cilia of ciliated disc. *b.* Ciliated disc. *c.* Peristome. *d.* Vestibule. *e.* Œsophagus. *f.* Contractile vesicle. *g.* Food vacuoles. *h.* Endoplast. *i.* Endosarc. *k.* Ectosarc. *l.* Cuticle. *m.* Axis of stem.

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3. The mouth of the bell is nearly filled by a structure (Fig. 4, *b*), which may be compared to the clapper of a bell, and which is known as the ciliated disc or *epistome*. Its outer or upper surface is slightly arched; and there is a second circlet of long cilia (Fig. 4, *a*) around its edge.

4. Around the greater part of its circumference the ciliated disc is united to the peristome; but on one side there is an open space, the *vestibule* (Fig. 4, *d*), which is bounded internally by the disc, and externally by the peristome.

5. Notice that, when the animal is fully expanded, the plane of the peristome makes an acute angle with the plane of the ciliated disc: the vertex being opposite the vestibule.

6. In the lower part of the bell notice a number of faint longitudinal striations which may, in favorable specimens, be seen to cover the whole surface of the bell up to the peristome.

b. The stem is cylindrical, and consists of an outer, transparent sheath (Fig. 4, *l*) and a central, darker axis (Fig. 4, *m*), which is not straight, but arranged in a loose spiral inside the tube formed by the outer sheath.

c. Make a sketch showing these points.

VII. Selecting an individual with a short stem, watch the process of contraction, and notice the following changes: —

a. The ciliated disc is first withdrawn into the bell by a process of rotation upon the peristome at a point opposite the vestibule.

b. The cilia of the peristome cease vibrating and fold in over the disc.

c. The peristome next folds inwards and contracts, and the body becomes nearly spherical.

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d. The stem is thrown into a spiral.

VIII. Notice that this order is reversed during expansion, which takes place much more slowly.

IX. The Structure of the Body.

As in Paramœcium, the body-substance consists of three layers, — the cuticle, the ectosarc, and the endosarc.

a. The endosarc (Fig. 4, *i*, Fig. 5, *d*) occupies the central region of the body, but does not extend into the stem. Its transparent, colorless sarcode contains numerous minute, dark-colored granules, and it also contains food vacuoles (Fig. 4, *g*), oil-drops, and foreign border such as have been noticed in Paramœcium and Amœba.

1. Careful observation of a single vacuole or solid particle will show that the whole semi-fluid endosarc is in motion. The motion is most vigorous near the surface, and least so in the centre. If the animal be placed with the ciliated disc above, and the vestibule away from the observer, the current will be found to flow down the left side, across the bottom, and up on the right side, as shown in Fig. 5, by the arrows.

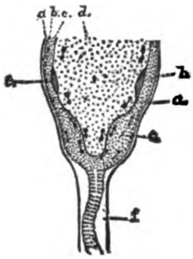

FIG. 5.

FIG. 5. — Diagram of a vertical section of Vorticella nebulifera, to show the arrangement of the layers of the body (from Everts).

a. Cuticle. *b.* Contractile layer of Ectosarc. *c.* Inner layer of Ectosarc. *d.* Endosarc. *e.* Endoplast. *f.* Stem.

2. Notice the movements of the semi-fluid endosarc caused by changes in the shape of the body, and carefully distinguish these movements from the constant circulation of the endosarc.

b. The ectosarc (Fig. 4, *k* and Fig. 5, *c*) is thin above; but it gradually thickens below, and it forms the entire axis of the stem. The line separating it from the endo-

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sarc is more definite than it is in Amœba or Paramœcium. The ectosarc is uniformly granular, and it contains no food vacuoles, oil-drops, or foreign bodies.

3. The ectosarc, like the endosarc, is in constant motion; but, owing to the absence of large particles, the currents are very hard to discover. They flow in an opposite direction to those of the endosarc.

4. The longitudinal striations are restricted to the outer surface of the ectosarc, which is thus divided into a superficial muscular or contractile layer (Fig. 5, *b*), and a deeper unspecialized layer, (Fig. 5, *c*). The two are not sharply separated.

5. The contractile axis of the stem is a continuation of the contractile layer of the ectosarc. Its upper end is distinctly striated or divided into a series of parallel, dark-colored transverse bands, separated from each other by mere transparent spaces.

c. The transparent, elastic cuticle (Fig. 4, *l*, and Fig. 5, *a*) covers the whole outer surface, and is thin upon the disc and peristome; thicker upon the bell, and thickest in the stem. A very high power shows that its surface is sculptured by parallel rows of fine dots. The loose spiral, formed by the contractile axis of the stem, is attached to the cuticle only on one side; and when the axis contracts the tubular cuticle is thus thrown into a spiral, by the flattening of which the animal is drawn back to its point of attachment. When the contractile axis relaxes, the elasticity of the cuticle straightens the stem, and pushes out the body of the animal. When the peristome and disc are retracted, the cuticle folds in with them, and its elasticity causes the body to expand as soon as the force is relaxed. The rapid contractions of the animal are thus due to the contractile power of the outer layer of

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ectosarc, while the more gradual extension is due to the elasticity of the cuticle.

X. Make a sketch showing as many of these points as possible.

XI. The Digestive Organs.

The solid particles of food are taken directly into the endosarc, as they are in Paramœcium and Amœba; but the apparatus for the ingestion of food is quite complicated. It can be examined to the best advantage in specimens which have been fed with finely-powdered carmine or indigo. In such a specimen notice: —

a. The currents produced by the cilia of the peristome and disc. These cilia act in such a way as to drive some of the particles into the vestibule.

b. When the vestibule becomes filled with the colored particles, it is seen to be continuous with a horizontal tube, the *œsophagus* (Fig. 4, *e*), which runs under the disc into the endosarc.

1. Notice that the walls of the œsophagus are covered with small cilia, which keep the particles in motion, and tend to drive them towards the inner end.

2. Notice that some of the particles are drawn out of the vestibule and thrown away from the body, and a violent contraction of the peristome and disc occasionally drives all the particles out of the œsophagus.

3. In very favorable specimens, the œsophagus and vestibule may be seen to be lined by a continuation of the cuticle.

4. At the inner end of the œsophagus is a small, slightly dilated *crop*, which is also ciliated and lined by the cuticle.

5. As the particles of food are drawn from the œsophagus into the crop, the cilia of the crop give them a whirl-

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ing motion, and thus gradually aggregate them into a little food ball.

6. From time to time the contractions of the body drive these pellets into the endosarc, where they form food vacuoles.

7. As the currents of the endosarc carry the food vacuoli around the body, the water and soluble portions are digested out and absorbed, and the indigestible portion is finally accumulated near the upper surface of the crop, into which it is finally drawn by a contraction of the body, to be expelled through the vestibule.

c. Make a sketch showing these points.

XII. As a rule only one contractile vesicle is present near the upper end of the bell. It presents no features which cannot be studied to better advantage in Paramœcium.

XIII. The endoplast is rather difficult to find in a living specimen; but it may be rendered visible by adding a drop of dilute acetic acid to the drop of water which contains the animal. It is a long, curved, club-shaped body (Fig. 4, *h*), which extends around two-thirds or more of the circumference of the body, and lies between the ectosarc and endosarc, as shown at *c* in Fig. 5. It is transparent, dark-colored, finely granular. There is no endoplastule as there is in Paramœcium.

IV. THE MULTIPLICATION OF VORTICELLA.

THE beginner cannot hope to overcome the difficulties which attend the attempt to trace all the stages in the life-history of an Infusorian; but a little patience will enable him to find isolated examples of most of the points which are to be noticed.

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I. The Multiplication by Fission.

a. Occasionally a Vorticella becomes permanently retracted, and the body becomes lengthened laterally; the peristome gradually disappears; the nucleus becomes more conspicuous; the food vacuoles and granules gradually disappear; the sarcode becomes transparent; and, after a time, the nucleus assumes a position at right angles to the stem, and the body shows traces of a vertical division into two, as shown in Fig. 7.

b. The nucleus soon divides into two portions, which separate from each other to become the nuclei of the two new animals. (Fig. 8).

c. The constriction next becomes more marked, and at or near each end of the long axis of the compound body a curved groove makes its appearance. This groove soon shows traces of ciliary action, and becomes converted into the peristome of one of the new animals.

d. The animals then become completely separated, as shown in Fig. 9. They assume the vase-like shape. The peristomes and discs become fully developed, and two perfectly-formed Vorticellæ are now mounted upon a single stem.

e. The stem gradually becomes forked.

f. Each of these animals may soon repeat the same process of division, thus building up a community by repeated fission.

II. The Formation of the Free Form.

a. Sometimes, after the completion of the division, one of the new animals is smaller than the other, and is situated nearly at right angles to the common stem.

b. This soon develops a crown of cilia around the fixed end of the body, as shown in Fig. 10.

c. It then detaches itself from the stem by violent movements, and swims away by means of its cilia.

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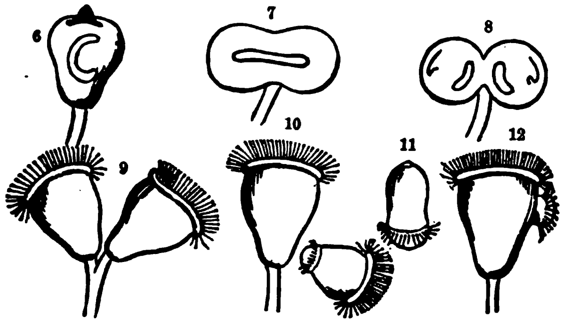
d. It soon loses its peristome and disc, and assumes the form shown in Fig. 11, the end which now carries cilia being that which was attached to the stem.



FIGS. 6, 7, 8, 9, 10, 11, and 12.

FIGS. 6–12. — Multiplication of Vorticella nebulifera. (Slightly altered from Everts.)

FIGS. 6, 7, 8, 9. — Stages in the process of multiplication by fission.

FIGS. 10, 11. — The formation of a free individual.

FIG. 12. — The process of conjugation.

III. The Process of Conjugation.

a. After swimming about for a time, it fastens itself, by what was originally its upper or peristomal end, to the side of the body of one of the ordinary fixed animals.

b. The two then gradually become fused into one body, as shown in Fig. 12. This process is essentially a process of sexual reproduction, in which the entire bodies of the two conjugating animals correspond to the two reproductive elements of one of the higher animals or plants. The compound body formed by their union corresponds to a fertilized egg or seed; and it soon begins to multiply again by division, although the precise method in which division takes place, after conjugation, varies greatly in different species of Vorticellidæ.

IV. Specimens may sometimes be found which have

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retracted the peristome and disc, and have secreted a thick layer of cuticle, or a *cyst*, around the spherical body. They sometimes become encysted while on a stem, or they may separate from the stem first. The encysted forms may retain their vitality for an indefinite period without food or moisture. Encystment sometimes takes place after conjugation, and sometimes apparently without conjugation.

V. CALCAREOUS SPONGE.

(*Grantia* [*Sycandra*] *ciliata*).

THE comparative simplicity of the structure of this sponge (Grantia ciliata) renders it peculiarly available for laboratory work.

It is a small, light-brown, nearly cylindrical, calcareous sponge, from half an inch to an inch long. Isolated individuals are sometimes found, but it is more frequently found in small crowded clusters; and each large sponge usually carries smaller ones, which have been formed as buds around its base.

It is quite common on the New England coast, in shaded places, at or near the low-water mark, upon piles, stones, or shells, as well as upon other sponges, hydroids, and tunicates.

The sponges should be placed in preserving fluid as quickly as possible after they are collected, and, if it is necessary to keep them alive longer than a few minutes, they should be placed in as great a quantity of fresh sea-water as possible, and kept shaded from the sun.

Some of the specimens should be preserved in alcohol, to study the general form and the arrangement of the calcareous skeleton; and others should be preserved in picric or chromic acid for histological work.

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The specimens which are to be preserved in alcohol should be placed in seventy-five per cent alcohol as soon as possible, and left for about twenty-four hours. They should then be transferred to eighty or eighty-five per cent alcohol, and left in that for about twenty-four hours, and they may then be preserved, until they are wanted, in ninety or ninety-five per cent alcohol.

The other specimens should be placed in a shallow pan or dish filled with a saturated solution of picric acid, and left for about ten hours. They should be transferred to seventy-five per cent alcohol, in which they should be left for about twenty-four hours, when they may be put into strong alcohol ninety or ninety-five per cent. In about twenty-four hours this alcohol should be poured off and renewed; and at the end of another day, if the alcohol has turned yellow, it should be again renewed; and so on, until the alcohol remains colorless. Examine one of the alcoholic specimens in a watch-crystal full of alcohol with a hand-lens, or with a very low power of the microscope, — ten or twenty diameters, and notice: —

I. The External Form.

a. The brown, cylindrical or vase-shaped body.

b. The opening, or *osculum*, at its distal or free end.

c. Smaller sponges, which have been formed by budding around the proximal end or base of the larger one.

II. Split the specimen with a razor or sharp scalpel through the long axis of the body, thus laying open the central cavity or *cloaca*. Examine the cut surface with a very low magnifying power or with a hand-lens, and notice: —

a. The *body cavity*, or *cloaca* (Fig. 13, *g*), a large cylindrical cavity, which occupies the long axis of the sponge.

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b. The *osculum*, or wide, round opening (Fig. 13, *b*), through which the cloaca communicates with the exterior.

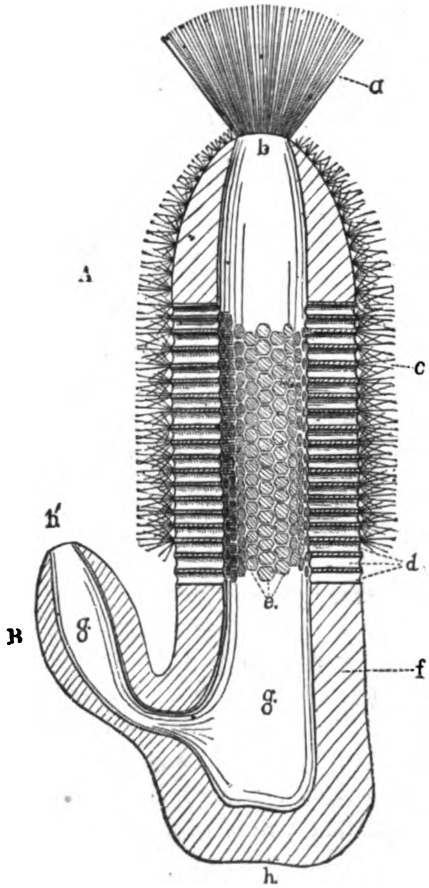

FIG. 13.

FIG. 13. — Longitudinal section of a calcareous sponge (Sycandra ciliata) magnified about ten diameters. (Drawn from nature by W. K. Brooks.)

A. Mature sponge. *B.* Bud. *a.* Crown of large spicules around osculum. *b.* Osculum. *b*[1]. Osculum of bud. *c.* Layer of spicules, shown in a part of the figure only. *d.* Radiating tubes, shown in a part of the figure only. *e.* Inner or cloacal apertures of the radiating tubes, shown in part of the figure only. *f.* Sponge flesh. *g.* Cloaca. *g*[1]. Cloaca of bud. *h.* Base or attached surface of sponge.

c. The wall of the cloaca, as shown by the section, is made up of:—

1. An outer, brown layer (Fig. 13, *c*), which a slight magnifying power shows to be made up of the projecting ends of the calcareous needles or spicules which form the skeleton of the sponge.

2. An inner, nearly white, layer: the sponge-flesh (Fig. 13, *f*). This layer is somewhat thicker than the outer

brown layer, except around the osculum, where it becomes thin, and ends in a narrow edge.

d. The circlet of long, slender spicules, which forms a collar or crown (Fig. 13, *a*) around the osculum.

e. The radiating tubes.

1. When slightly magnified, the inner surface of the cloaca will be seen to be filled with small polygonal openings (Fig. 13, *e*) the inner ends of the radiating tubes. These are not as regular as they are represented in the figure.

2. Upon the cut surface of the section of the sponge-flesh along the sides of the cloaca, the radiating tubes will be seen to be laid open longitudinally (Fig. 13, *d*). They are straight tubes, which penetrate the sponge-flesh at right angles to the long axis of the body, and opening on its outer surface, among the bases of the spicules, establish a communication between the outer surface and the cloaca.

f. Around the base of the sponge, notice the buds which are to give rise, by their detachment, to separate sponges; and observe, —

1. The cloaca of the bud (Fig. 13, *g*), which is in free communication with the cloaca of the large sponge.

2. The osculum, spicules, and radiating tubes of the bud, similar in every respect to those of the large sponge.

3. Notice that there is no boundary line between the sponge-flesh of the large sponge and that of the bud.

g. Make a sketch showing all these points.

III. The spicules. Cut a small piece from the specimen, and boil it for a short time in a test tube in caustic potash solution, in order to separate and clean the spicules. Allow them to settle to the bottom of the tube, and then draw up some of them with a medicine dropper, and

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placing them upon a slide, examine them with a magnifying power of 200 or 300 diameters, noticing: —

a. Great numbers of tri-radiate spicules, formed by three branches of about equal length, which meet at equal angles of 120°.

b. Long unbranched, slender, pointed, needle-like spicules.

c. Occasionally a second kind of tri-radiate spicule, formed by the union of a short branch to the middle of a long branch at right angles.

d. Make sketches of the spicules.

e. Wash them thoroughly with water, to remove all traces of the caustic potash, and add to the drop of water which contains them a drop of acetic or sulphuric acid. They soon disappear with active effervescence.

IV. Imbed half the sponge in paraffine in position for cutting longitudinal sections, and the other half for cutting transverse sections. Tolerably satisfactory sections may be cut from a sponge which, after being placed for about a minute on a piece of blotting-paper to absorb the alcohol, is allowed to harden in a small quantity of meltėd paraffine; but much more satisfactory sections may be obtained in the following manner: Place the sponge in absolute alcohol for about an hour and then lay it on blotting-paper to absorb the alcohol, and then place it in a dish large enough to hold ten or more times its volume. Fill the dish with turpentine, and add all the paraffine the turpentine will dissolve, and keep in a warm room for ten or twelve hours. Then melt some paraffine over a water-bath, and place the sponge in it, and keep it at the melting point for three or four hours. Fold the corners of a piece of writing-paper so as to form a box about an inch long, and half an inch wide and deep. Place the sponge

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in the box, fill with the hot paraffine, and allow it to cool. Cut a number of sections as thin as possible across the imbedded sponge with a sharp razor, and transfer them to a glass slide. Cover them with a mixture of equal parts of carbolic acid and turpentine to dissolve away the paraffine. After the sections become transparent, remove as much as possible of the carbolic acid and turpentine with a piece of blotting-paper, and cover them with a drop of Canada balsam, and cover with a thin glass cover. The balsam should be kept in a wide-mouthed bottle, loosely covered by a perforated cork, through which a glass-rod has been passed, and it should be taken up on the rod, and thus transferred to the slide. If the balsam is too stiff to drop readily from the rod, it may be liquefied by adding a small quantity of benzole. The carbolic acid and turpentine should also be kept in a bottle with a glass rod passed through the cork.

a. Examine the longitudinal sections with a power of two or three hundred diameters, and note: —

1. The cut sections of the radiating tubes; circular when cut perpendicular to their long axis.

2. The more common kind of triradiate spicules arranged around, and in the spaces between, the tubes.

3. The long needle-like spicules upon the outer surface.

4. Make a sketch of a longitudinal section.

b. Examine a transverse section with the same power, and notice: —

1. The radiating tubes (Fig. 14, *b*, *b*, *b*) laid open longitudinally. Each tube is divisible into three regions:

(i.) The narrow, inner aperture, through which its cavity communicates with the cloaca.

(ii.) The long cylindrical canal, which traverses the sponge-flesh from its outer surface to the cloaca.

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(iii.) The small aperture or inhalent pore (Fig. 14, *g*), through which the tube opens on the outer surface of the sponge.

(iv.) Occasionally two radiating tubes communicate through an opening in the wall between them.

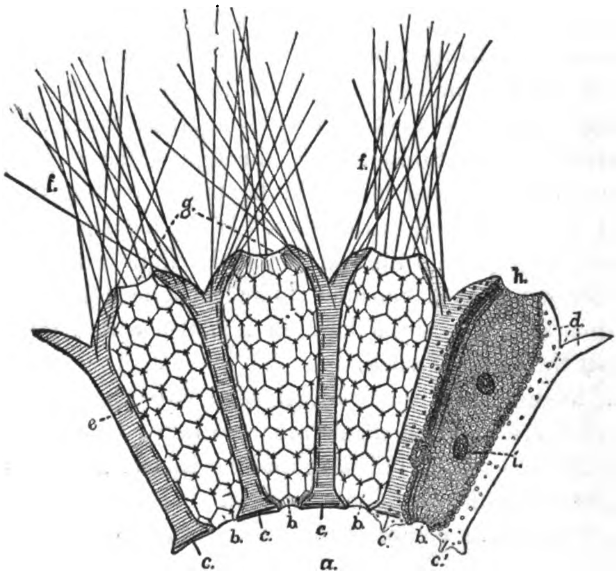

FIG. 14.

FIG. 14. — Tranverse section of a calcareous sponge (Grantia ciliate) magnified about two hundred and fifty diameters. The section shows the cavities of four radiating tubes. The spicules are represented in the three on the left, and the cells, nuclei, and eggs, are shown in the one on the right.

a. Cloaca. *b, b, b, b.* Cavities of the radiating tubes. *c, c, c, c', c'.* Tri-radiate spicules projecting into the cloaca. *d.* The syncitium. *e.* Skeleton of tri-radiate spicules around the tubes. *f.* Long needle-like spicules. *g.* Inhalent pores. *i.* Eggs.

2. The needle-shaped spicules (Fig. 14, *f*), which are arranged in bunches or stacks over the inhalent pores.

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3. The tri-radiate spicules (Fig. 14, *e*), which form a framework or skeleton between the tubes.

The second, or more rare kind of tri-radiate spicules (Fig. 14, *c*), which are placed around the wall of the cloaca in such a way that the short branch of the spicule projects into the cavity of the cloaca.

4. Make a drawing showing these points.

V. Histological structure.

Most of the following points may be made out in a specimen prepared as above, but they are more satisfactorily shown in stained sections of a specimen which has been hardened in picric acid.

As eosin is a very convenient staining fluid, which brings out the points to be noticed with sufficient clearness, the sponge may be placed for half an hour in a very dilute solution of eosin in water. It should then be returned to absolute alcohol for a few minutes, and then imbedded in paraffine, as above described. Cut a number of transverse sections, mount them in balsam, and examining them with a power of three or four hundred diameters, notice: —

a. The *syncitium*, or granular protoplasm (Fig. 14, *d*, *d*), with scattered nuclei, which covers the outer surface of the sponge, and lines the cloaca, and also fills the spaces between the radiating tubes. On the side of the cloaca it extends, as a thin web, to the tips of the spicules, which project into the cavity.

b. The layer of cellular epithelium, or *endoderm* (Fig. 14, *h*) which lines the radiating tubes. With a high power, in favorable specimens, each cell may be seen to carry a single long cilium.

c. The remains of the spicules imbedded in the syncitium.

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d. The large granular oval *eggs* (Fig. 14, *i*) which lie in the partitions between the radiating tubes, under the layer of endoderm.

VI. THE STRUCTURE AND GROWTH OF THE ASEXUAL FORM OF A CAMPANULARIAN HYDROID.

(*Eucope obliqua*).

Although this description was written from a specimen of the above species, almost any Campanularian Hydroid may be used to verify the points, since the differences between them are slight.

They may be found in abundance, in the form of brown moss-like tufts, near low-tide mark, on plants and stones, on the lower surfaces of overhanging rocks, on the timbers of wharves, the bottoms of boats, or on floating drift-wood or algæ.

The living animals should be examined in sea-water, as it is difficult to preserve satisfactory specimens. If specimens are to be preserved for laboratory work, select those which are as clean and free from foreign matter as possible, and plunge them, alive, into a saturated solution of picric acid in fresh water. In three or four hours they may be transferred to seventy-five per cent alcohol, or to a mixture of equal parts of alcohol, glycerine, and sea-water. After about twelve hours the specimens which have been placed in alcohol may be transferred to ninety per cent alcohol for permanent preservation.

I. Examine with a low power a portion of a living colony in a watch-crystal of sea-water, or a portion of a preserved specimen in a small quantity of the preserving fluid, and notice :—

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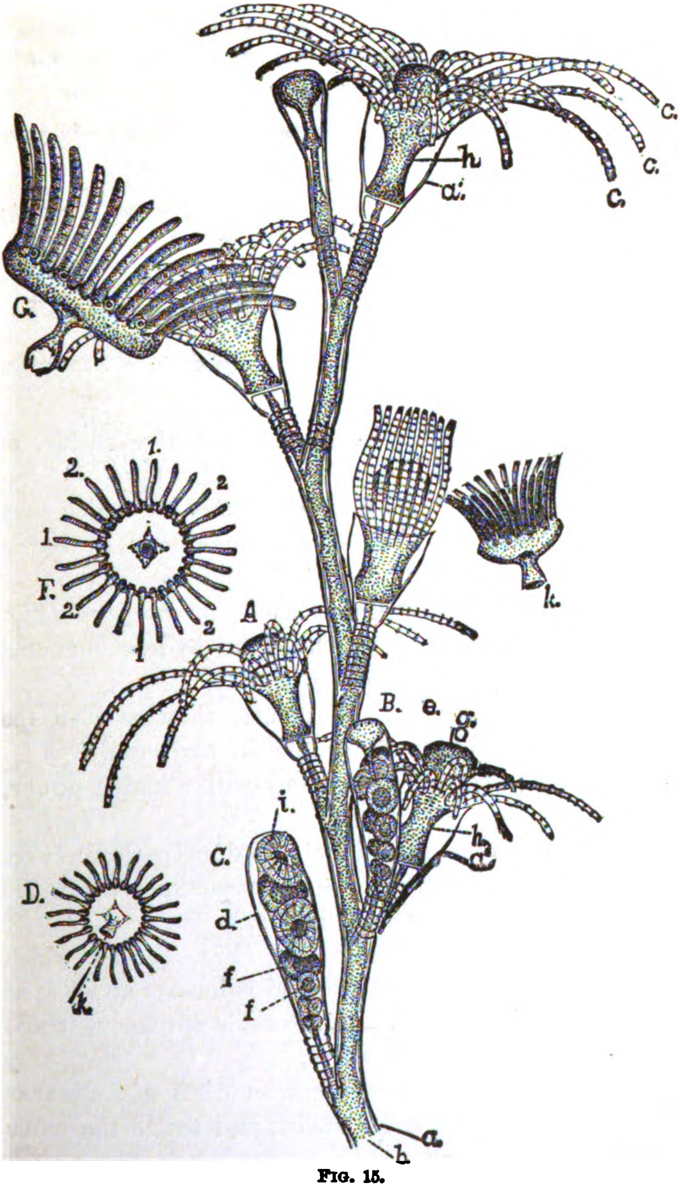

FIG. 15.

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Fig. 15. — Hydranths, reproductive calyces and medusæ of an undescribed species of Eucope, magnified about fifty diameters, from a living specimen. Drawn by W. K. Brooks.

***A, A, A.* Hydranths or nutritive zooids.**

***B.* A reproductive calycle, showing the blastostyle and very young medusa-buds.**

***C.* An older reproductive calycle, with fully-formed medusæ.**

***D.* View of the lower or oral surface of a young medusa, a few minutes after its escape from the reproductive calycle.**

***E.* Side view of same.**

***F.* Medusa about an hour older.**

***G.* Side view of medusa, about thirty-six hours after its escape from the reproductive calycle.**

***a.* Perisarc. *b.* Endosarc. *c.* Tentacles of hydranth. *g.* Manubrium. *h.* Body of hydranth.**

a. The vase-shaped, tentaculated, nutritive zoöids, or *hydranths* (Fig. 15, *A*, *A*, *A*).

b. The branched stem, or *hydrocaulus* by which they are united to each other, and to a common base, or *hydrorhiza*.

c. The transparent chitinous shell, or *perisarc* (Fig. 15, *a*) which covers the hydrorhiza, the hydrocaulus, and portions of the hydranths.

d. Make a sketch of these points, showing also the arrangement of the hydranths upon the hydrocaulus.

II. Examine a portion of a colony with a higher power, and note: —

a. The transparent cylindrical sheath of perisarc (Fig. 15, *a*) which is annulated above and sometimes below the points where the hydrocaulus divides.

b. The *coenosarc* or fleshy axis (Fig. 15, *b*) which occupies the cavity of the tube, and is loosely attached at intervals to its inner wall. In favorable specimens it will be seen to consist of three layers.

1. The outer layer, or *ectoderm* consists of somewhat transparent cells with large nuclei, and forms the outer surface of the coenosarc.

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2. The inner layer, or *endoderm*, is of about equal thickness, but the cells which compose it are more opaque and granular.

3. A thin transparent *supporting layer* with well-defined edges will be seen to separate the outer from the inner layer.

c. In the centre of the coenosarc notice the tubular body cavity.

d. In a living specimen note that the granular matter which fills the cavity is kept in circulation by the action of cilia which arise from the inner surface of the endoderm.

e. Make a sketch showing these points.

III. Examine the hydranths, and having found one which is expanded, note: —

a. The open cup or vase, the *hydrotheca* (Fig. 15, *a′*) formed by the expansion of the perisarc.

b. The crown of tentacles (Fig. 15, *c*) arranged in a circle.

c. The rounded prominence, or *manubrium* (Fig. 15, *g*) which projects into the space between the tentacles, and carries the mouth upon its free end.

d. The body (Fig. 15, *h*) of the hydranth, made up like the stem of three layers.

1. The thin transparent ectoderm.

2. A sharply-defined supporting layer.

3. A very thin layer of endoderm, made up of large opaque vacuolated cells, the inner or free ends of which carry cilia.

e. Notice that the body cavity of the hydranth is simply an enlargement of that of the hydrocaulus. It is lined with cilia, and the particles of food which it usually contains may in the living specimen be seen to circulate through the stem.

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f. Make a drawing of a hydranth, showing all these points.

IV. Examine a tentacle with a higher power, and notice that it is made up, like the hydrocaulus and hydranth, of three layers.

a. The ectoderm forms a thin, highly elastic, and contractile layer (Fig. 19, *a*) which contains numbers of small oval bodies, the *nematocysts* or lasso cells.

b. The supporting layer (Fig. 19, *b*) forms a thin transparent line between the ectoderm and endoderm.

c. The endoderm (Fig. 19, *c*) completely fills the centre of the tentacle, and consists of large cells with a distinct cell wall and a large granular central nucleus, which is attached to the wall by irregularly branched protoplasmic threads.

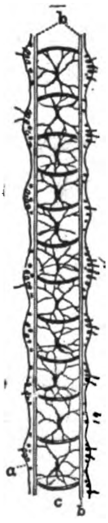

FIG. 19.

FIG. 19. Part of a tentacle, magnified two hundred and fifty diameters.
a. Ectoderm. *b*. Supporting layer. *c*. Endoderm.

d. In a surface-view notice the longitudinal muscular fibres, which lie just outside the supporting layer of the tentacle.

e. In a living specimen notice that the tentacles are retracted and extended by contractions of the elastic substance of the body, and not by the folding of the tentacle upon itself.

f. Make a drawing of a tentacle, showing these points.

g. Crush a portion of a tentacle, by pressure on the cover-glass, and examining it with a high power, notice the *nematocysts* which are thus set free. When fully extended, each (Fig. 20) consists of a small oval capsule, and a very long slender filament, with three barbs or hooks near its proximal end.

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V. Search among the tips of the branches of a colony for the various stages in the process of formation of a hydranth by budding, and notice: —

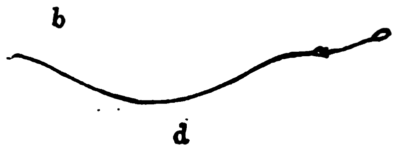

FIG. 20.

FIG. 20. — A discharged nematocyst, magnified three hundred and fifty diameters.

a. A stage in which the bud is a simple, nearly cylindrical knob at the end of a branch (Fig. 16). The coenosarc is in contact with the thin investing layer of perisarc (Fig. 16, *a*), and its distal end is made up of a thick layer of ectoderm (Fig. 16, *b*) and a mass of loose endoderm cells (Fig. 16, *c*). At a very early stage the cavity of the stem does not extend into this mass.

b. A stage in which the bud (Fig. 17) is club-shaped, — the perisarc at the tip of the stem very thin, while the ectoderm is very thick. The body cavity (Fig. 17, *d*) now extends into the bud, and the endoderm cells (Fig. 17, *c*) form a true inner layer. The coenosarc has begun to separate from the perisarc at the sides, and the outline of the body of the hydranth can be recognized.

c. In a more advanced stage (Fig. 18) the shape of the body is well marked, and the coenosarc is more free from the perisarc, which still entirely covers it.

d. In a more advanced stage the perisarc is ruptured and expanded to form the hydrotheca, and the manubrium and budding tentacles can be seen.

e. Make a sketch showing the various stages in the process of budding.

f. Notice that in the living specimen the particles of food are carried through the hydrocaulus into the body

cavity of the bud long before this has a mouth of its own.

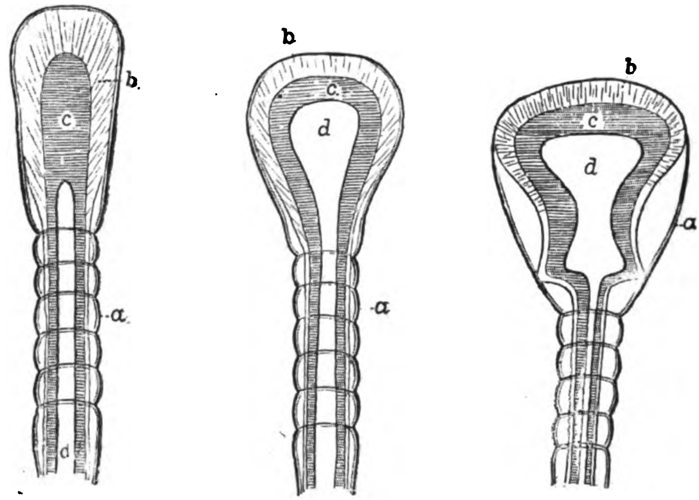

FIG. 16. FIG. 17. FIG. 18.

FIGS. 16, 17, and 18. — Three stages in the formation of a hydranth by budding, magnified one hundred and fifty diameters. (Drawn from nature by W. K. Brooks.)

a. Perisarc. *b.* Ectoderm. *c.* Endoderm. *d.* Body cavity.

VI. Place a small healthy colony in a good supply of fresh sea-water, and cutting some of the hydranths and buds from the tips of the stems with a sharp pair of scissors, trace their reproduction by a process which is very similar to the normal method of budding. During the experiment, which occupies several days, the water should be changed frequently, and it may require three or four days for the colony to become sufficiently accustomed to its confined life to commence the process.

Confinement in too small a quantity of water often causes certain abnormal changes which may be noticed.

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The hydranths drop off, and the tips of the branches grow very rapidly, sending off long contorted transparent prolongations.

By changing a specimen from a small quantity of water to a larger quantity, the hydranths can be made to grow again, and this process can be repeated several times.

VII. THE STRUCTURE OF AN OCELLATE HYDRO-MEDUSA.

(*Mnemopsis Bachei.*)

As the small size and flat shape of the medusa stage of the hydroid described in the last section render it somewhat unfavorable for laboratory work, the student should, before studying it, make himself acquainted with the structure of one of the larger hydro-medusæ.

The species which is shown, magnified ten diameters, in Fig. 21, is very abundant during the summer along the Atlantic coast, and it is therefore a good form to select for study. Specimens may usually be procured by dipping at the surface of the ocean on quiet evenings with a surface-net. The net should be made of medium bolting-cloth, and should be about three inches deep, with a wire rim about six inches in diameter, fastened to a short handle. In using it, fill a bucket about half-full of fresh sea-water, and after dipping or skimming gently along the surface of the ocean for about a minute, insert the net into the bucket, and wash it in the water to dislodge any medusæ which have adhered to it. This process of dipping and washing should be kept up for an hour or more; and in washing the net, care should be taken that the rim does not dip below the surface of the water in the bucket, as valuable specimens might thus be dipped out of the bucket and thrown away.

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The most favorable time for all kinds of surface-collecting is a calm evening, when the water is phosphorescent; and in most localities, especially on low sandy coasts, a greater variety of forms will be met with at high water than at other times.

After the bucket with its contents has been carried home, a small quantity of the water should be dipped up in a small beaker or a tumbler with smooth sides, and held before a light for examination. The collection will probably be found to contain numbers of small rounded nearly hemispherical transparent medusæ, and these may be picked out with a dipping-tube and preserved for examination in small aquaria or beakers of fresh sea-water.

Most of the points in this description may be made out by the examination of living specimens, but they may be preserved for winter work if necessary. The most satisfactory method of preservation for microscopic examination is by the use of osmic acid. The specimens to be preserved should be placed alive in a large watch-crystal full of sea-water, and to this fifteen or twenty drops of one per cent solution of osmic acid in distilled water should be added.

As soon as the specimen begins to turn dark, which will be in five or ten minutes, pour off the water and fill the watch-crystal with new sea-water, and pour this off in five or ten minutes and renew once more. This should be done several times to wash out all traces of the acid. The specimen may then be strained in dilute picro-carmine for about an hour, and it may then be preserved in a mixture of equal parts of ninety-five per cent alcohol, sea-water, and glycerine. If osmic acid cannot be procured, satisfactory specimens can be preserved with picric acid. The specimens should be placed in a flat-bottomed dish

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filled with a saturated solution of picric acid in fresh water, and left for eight or ten hours. Each specimen should then be placed, by itself, in a small bottle of very dilute alcohol; about forty per cent. In about half an hour this should be poured off and renewed, and the process repeated until the alcohol shows no trace of a yellow color. After the specimen has remained for about half an hour in the last alcohol, pour off all but enough to cover it, and add strong alcohol, a few drops at a time, at intervals of about five minutes, until the bottle is filled.

The specimen should be examined in some of the fluid from its own bottle.

I. The General Structure. Examining a specimen in a watch-crystal, with a low power of the microscope, or with a hand-lens, notice:

1. The transparent gelatinous *umbrella* (Fig. 21, *a*, 25, *a*) which makes up the greater part of the body. The outlines are sharp and regularly curved in a living specimen, but they are usually somewhat shrunken and distorted in a preserved specimen.

a. The portion of the umbrella which is at the top in Fig. 21, and which, from its relation to the mouth, may be called the ab-oral portion, is greatly thickened, and the outer and inner surfaces are separated from each other by the elastic gelatinous substance of the umbrella.

b. At the lower or free edge (Fig. 21, *b*), the gelatinous substance gradually diminishes in thickness.

2. The *sub-umbrellar cavity* or space (Fig. 25, *b*) under or inside of the umbrella.

3. The *velum*, or muscular horizontal diaphragm (Figs. 21 and 25, *c*) which runs inwards around the lower edge of the umbrella, over the opening of which it forms a flat

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partition, which reduces the external opening of the sub-umbrellar cavity to a small circle (Figs. 21 and 25, *d*). This opening varies in size according to the degree of expansion or contraction of the velum.

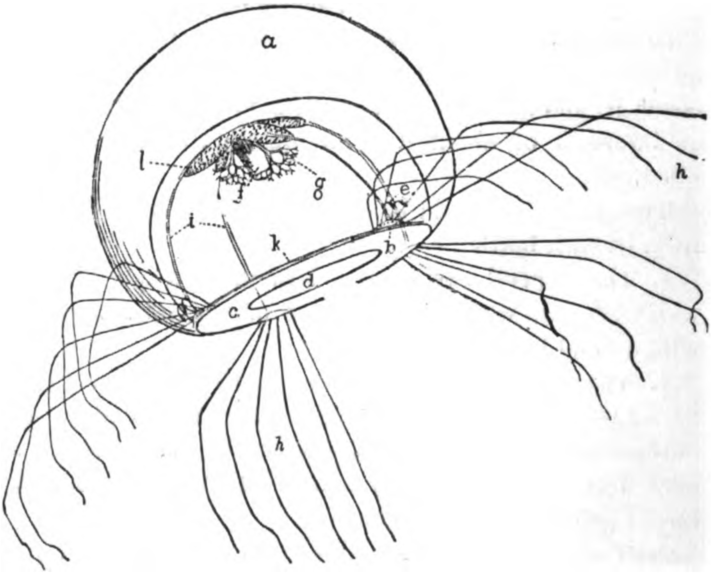

FIG. 21

FIG. 21. — Mnemopsis Bachei (southern variety) drawn from a living specimen, magnified about ten diameters. (Drawn from nature by W. K. Brooks.)

a. Umbrella. *b.* Sensory bulb. *c.* Velum. *d.* Aperture of velum. *e.* Club-shaped tentacles. *f.* Manubrium. *g.* Oral tentacles. *i.* Radiating chymiferous tubes. *k.* Circular chymiferous tube. *l.* Reproductive organs. *h.* Radial tentacles.

4. The four bunches of *radial tentacles* (Figs. 21 and 25, *h*) which spring from the lower margin of the umbrella, outside the velum. In the living medusa these tentacles are very extensile, and their length may be equal to or

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greater than the diameter of the umbrella, but in preserved specimens they are usually much contracted.

5. The *stomach*, or manubrium (Figs. 21 and 25, *f*) which is suspended from the inner surface of the umbrella, or *sub-umbrella*, and hangs down into the sub-umbrellar cavity. The manubrium consists of:

a. Four dichotomously-branched oral tentacles (Figs. 21 and 25, *g*), upon the manubrium.

b. The *mouth*, an opening situated between the bases of these tentacles, and serving to put the cavity of the manubrium into communication with the cavity of the sub-umbrella.

c. The body, or manubrium proper, with its central cavity, or stomach.

6. *The chymiferous tubes:* a set of prolongations of the stomach into the substance of the umbrella. This system consists of four radial tubes, and a circular tube.

a. The four radiating chymiferous tubes (Figs. 21 and 25, *i*) run outwards and downwards from the point where the manubrium hangs from the sub-umbrella, and they may be traced down to the free edge, just above the insertion of the velum. They lie near the sub-umbrellar surface, but they are entirely surrounded by the gelatinous substance of the umbrella. Observe that they are equidistant and separated from each other by an arc of ninety degrees. Observe, too, that each of them lies in the same place with one of the bunches of radial tentacles.

b. The circular chymiferous tube (Figs. 21 and 25, *k*) runs around the free edge of the umbrella just above the insertion of the velum.

c. Notice that the radiating tubes open into the circular tube, so that the whole system is in direct communication

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with the stomach. In a living specimen the system of tubes and the cavity of the manubrium are ciliated, and particles of partially-digested food may be seen circulating through them.

7. The *reproductive organs:* four long, crenated, opaque, ribbon-like bodies (Figs. 21 and 25, *l*) between the inner surfaces of the radiating chymiferous tubes and the sub-umbrella.

8. The *ocelli:* dark pigment spots, at the bases of the radial tentacles.

9. Lay a specimen open by a cut, with a sharp razor, through the umbrella and the long axis of the manubrium, and examine again in this longitudinal section all the structures which have been described.

10. Make a drawing showing all these points.

11. Study the manner in which the living animal moves through the water, by contractions of the umbrella.

II. The more minute details of structure may most of them be made out by the examination of a living specimen with high powers, but it is much better to use preserved specimens, as the active movements of the living animal render careful observation difficult. If working at the seashore, place a living specimen in a watch-crystal of sea-water, and add fifteen or twenty drops of one per cent solution of osmic acid. As soon as the specimen begins to turn dark, which will be in two or three minutes, pour off the water, and wash the specimen several times in fresh sea-water, to get rid of all traces of the osmic acid. Stain it for about half an hour in very dilute picro-carmine, and then place it in a fluid composed of one-third glycerine and two-thirds water, and with a sharp pair of scissors cut off one of the bunches of radial tentacles, and mount it

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on a glass slide with a thin glass cover, in a drop of the dilute glycerine, and examine it with a magnifying power of one hundred and fifty to three hundred diameters. If osmic acid cannot be procured, mount in the same way a portion of a specimen which has been preserved in picric acid, as already directed.

1. Observe that the tentacles (Fig. 22, *a*, *a*, *a*) are arranged in pairs on the sides of the plane of one of the radial chymiferous tubes.

The number increases with age, and those nearest the middle are the oldest.

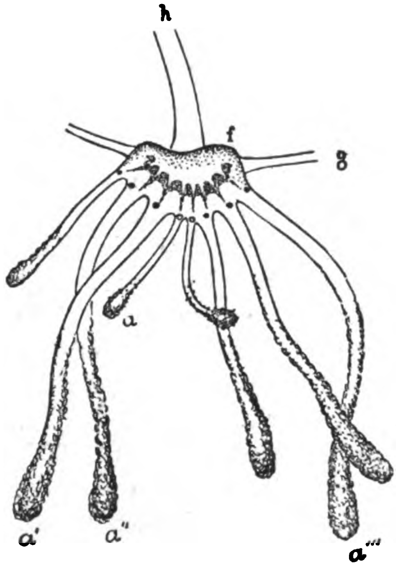

FIG. 22.

FIG. 22. — Sensory bulb, and bunch of radial tentacles, from a living specimen, magnified about eighty diameters. (Drawn from nature by W. K. Brooks.)
a. Club-shaped tentacles. *a'a''a'''*. Extensile tentacles. *f*. Sensory bulb. *g*. Circular chymiferous tube. *h*. Radiating chymiferous tube.

2. The pair nearest the median line (Fig. 22, *a*) are somewhat different from the others. They are shorter, less contractile, and are made up of an enlarged base which carries an ocellus, a slender shaft, and an enlarged, club-shaped terminal portion.

3. The ocellus at the base of this tentacle is a spherical accumulation of pigment granules, in the centre of which is a transparent, highly refractive spherical lens.

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4. The other tentacles are much larger, and are capable, in the living animal, of great extension and retraction; each will be found to be made up of: —

a. A central axis of endoderm cells, arranged in a single row.

b. A transparent supporting layer, which surrounds the endoderm cells, and may be seen in optical section, as a well-defined transparent band on each side of the endodermal axis.

c. The layer of longitudinal muscular fibres, which lies just outside the supporting layer.

d. The thin layer of ectoderm which forms the outer surface of the tentacle, and is filled with nematocysts.

5. The ocelli at the bases of these tentacles are somewhat smaller than those on the club-shaped tentacles, and the lenses may be absent.

6. The sensory bulb. The tentacles do not spring directly from the edge of the umbrella, but are carried upon a somewhat triangular enlargement, the sensory bulb (Fig. 22, *f*).

This is an enlargement of the margin of the umbrella, at the point where a radiating chymiferous tube (Fig. 22, *h*) joins the circular tube *g*. The cavity of the bulb is filled by an enlargement of these tubes which sends diverticula off towards the bases of the tentacles, and is marked by dark pigment.

7. In the cut ends of the chymiferous tubes notice the large opaque granular endoderm cells which line them.

III. The *mouth tentacles.* Cut off one of the branched mouth tentacles: mount it in the same way and examine it, first with a low power, and then with a higher power.

1. With a low power notice that the main trunk divides into two equal branches, and each of these again into two,

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and so on (Fig. 23), until a great number of small terminal branches is formed. Notice the round knobs at the ends of the terminal branches.

2. Examine one of the main trunks with a higher power, and notice: —

a. The double layer of large endoderm cells (Fig. 24, *a*) which forms the solid axis of the tentacle.

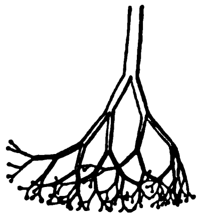

FIG. 23.

FIG. 23. — An oral tentacle, magnified about eighty diameters. (Drawn from nature by W. K. Brooks.)

b. The supporting layer.

c. The muscular layer (Fig. 24, *b*).

d. The ectoderm, with a few scattered nematocysts.

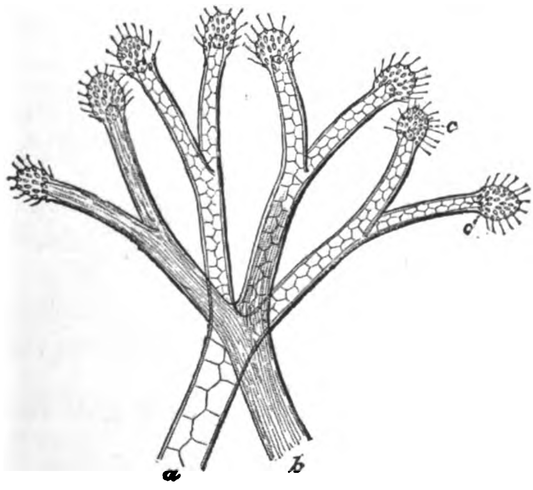

FIG. 24.

FIG. 24. — The tips of two branches of an oral tentacle, magnified two hundred and fifty diameters, from a picric acid specimen. (Drawn from nature by W. K. Brooks.)

a. The endoderm cells. *b.* The muscular layer. *c.* Battery of nematocysts.

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3. Examine the bulb at the tip of one of the branches, and notice that the endoderm is wanting here, while the greatly thickened ectoderm is packed with large nematocysts.

IV. Cut off a portion of the manubrium, and teazing it out in a drop of glycerine, notice the large granular endoderm cells which line its cavity, the transparent ectoderm cells which cover its outer surface, and the supporting layer between the two.

V. Examine the inner surface of a piece of the umbrella, and notice: —

1. The scattered nuclei of the greatly-flattened ectoderm cells which cover it.

2. Under these the layer of longitudinal muscular fibres which encircles the sub-umbrella, and which, by its contraction, drives the water out of the cavity, through the opening of the velum.

3. Here and there a dark brown stellate *ganglion cell*, which consists of a central body with a nucleus, and two or three long, fine, radiating nerve-fibres.

4. Along the lines of the radiating chymiferous tubes, notice a second layer of muscles, perpendicular to the circumference of the umbrella.

VI. Examine a piece of the velum, and notice: —

1. An outer layer of cells, continuous with those upon the outer surface of the umbrella.

2. An inner layer, continuous with those on the sub-umbrellar surface.

3. A thin, transparent, supporting layer, separating these two layers of cells.

4. The muscular layer of the velum, between the supporting layer and the inner layer of cells.

VII. The *nerve-ring*. Examine a piece of the lower

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edge of the umbrella, and on its outer surface, just above the insertion of the velum, notice a dark-colored band (Fig. 25, *m*), which encircles the body parallel to, but just outside of and below, the circular chymiferous tube. In favorable specimens this band may be seen to consist of: —

1. A surface-layer of thickened ectoderm cells, with cilia upon their outer surface.

2. An inner layer of nerve-fibres, with a few scattered ganglion cells like those of the sub-umbrella.

VIII. Examining pieces from various parts of the body, trace out the general relations of the various layers which have been noticed, and observe: —

1. The ectoderm (Fig. 25, *1*). This covers the outer surface of the umbrella, the radial tentacles, the outer surface of the velum, the inner surface of the velum, the sub-umbrella, the outer surface of the manubrium, and the outer surfaces of the mouth tentacles.

a. On the outer surface of the umbrella the ectoderm cells are very much flattened, and as they are easily detached, they may not be present in a preserved specimen. In a specimen which has been recently hardened in osmic acid, their nuclei may be seen in a surface-view of the umbrella.

b. At the lower edge of the umbrella the ectoderm suddenly becomes thickened to form the ciliated epithelium of the nerve ridge.

c. On the radial tentacles the ectoderm forms a thin layer with nematocysts.

d. The outer and inner layers of epithelium of the velum are continuous with each other at the free edge, and are formed of thickened cells.

e. The ectoderm of the sub-umbrella is very thin, and only the scattered nuclei can be recognized.

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f. On the manubrium the ectoderm cells are again thickened, and have a few scattered nematocysts.

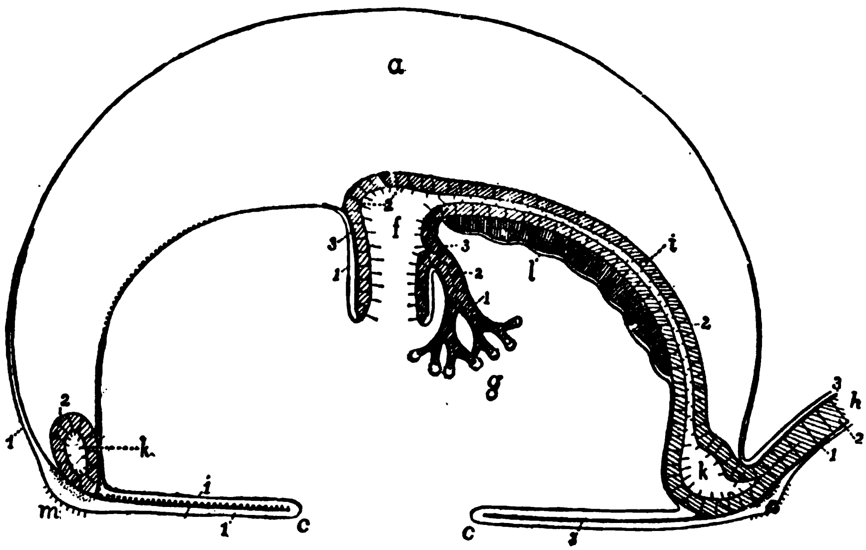

FIG. 25.

FIG. 25. — Diagram to show the arrangement of the layers of the body of a Hydro-Medusa, as seen in a vertical section. The section is represented as passing through a radiating chymiferous tube on the right side, and through the space between the tubes on the left.

a. Umbrella. *c.* Velum. *d.* Aperture of velum. *e.* Cavity of subumbrella. *f.* Manubrium. *g.* Oral tentacles. *h.* Radial tentacle. *i.* Radiating chymiferous tube. *k.* Circular chymiferous tube. *l.* Reproductive organ. *m.* Sensory ridge.

g. The ectoderm of the mouth tentacles is very thin except at their tips, where it forms a knob-shaped battery of nematocysts.

2. The endoderm (Fig. 25, *2*). This layer lines the stomach and chymiferous tubes, and sends solid processes out to the tips of the oral and radial tentacles.

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3. The supporting layer (Fig. 25, *3*) separates the endoderm from the ectoderm in the manubrium and in the tentacles, and it also runs out between the two epithelial surfaces of the velum.

VIII. THE MEDUSA STAGE OF A CAMPANULARIAN HYDROID.

I. Examine specimens of the hydroid which was described in Section VI., until one is found which has reproductive calycles (Fig. 15, *B* and *C*). These will usually be found near the bottom of the hydrocaulus. Having found a specimen, cut off the section of the stem which carries the reproductive calycles, and place it upon a slide under a cover glass, in a drop of sea-water, for microscopic examination. Examining it with a low power, fifty to one hundred diameters, notice: —

a. The *gonangium*, or capsule of perisarc (Fig. 15, *d*) which corresponds in general outline and in its position upon the stem, to the hydrotheca of one of the ordinary nutritive hydranths, although it is longer, and is closed at its free end.

b. The *blastostyle*, or rudimentary hydranth (Fig. 15, *c*). This consists of a long slender stem or axis, which corresponds to the body of one of the nutritive hydranths; and a club-shaped tip, or manubrium, with scattered nematocysts.

There are no tentacles, and the manubrium has no terminal orifice or mouth; but the body layers which have been examined in the hydranth may be seen in the blastostyle, and there is a central ciliated body-cavity, continuous with the cavity of the hydrocaulus. In transparent specimens particles of food may be seen to pass up the stem into the blastostyle.

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c. The medusa-buds (Fig. 15, *f*) arranged around the blastostyle. Those nearest its free end are the oldest and largest, and when fully developed (Fig. 15, *c*) they almost entirely fill the cavity of the gonangium. When ready to be discharged each will be seen to be a flattened medusa, with a number of marginal tentacles folded down over the bottom of the umbrella (Fig. 15, *i*).

d. Make a drawing of a reproductive calycle, showing these points.

II. The general structure of the medusa. Place two or three stems, with ripe calycles, in a good supply of fresh sea-water, and after a day or two, carefully examine it for young medusa, which will be found swimming in the water, usually at the surface. They are much smaller than the medusa described in Section VII., and the nearly flat, disc-shaped umbrella has tentacles around its entire edge. In swimming the umbrella is usually carried turned wrong side out, as shown in Fig. 15, *E*, with the manubrium projecting from the centre of the convex surface, and the tentacles turned up at their bases, so as to point towards the ab-oral surface.

a. If possible, notice the escape of a medusa from the reproductive calyx. At the time of escape the tentacles are folded down, as shown at *i*, but within a few minutes they straighten, as shown at *D*, and in fifteen or twenty minutes the medusa begins to swim actively, as shown at *E*, by vigorous flaps of its tentacles. It grows rapidly, and in about an hour it appears as shown at *F*.

b. Pick out one of the larger specimens with a dipping-tube; and placing it in a watch-crystal with sea-water, examine it with a low power, noticing: —

1. The manubrium (Fig. 15, *D* and *E*, *k*) with its large terminal mouth, and stomach-cavity; notice that the

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edges of the mouth are entire, without lobes or oral tentacles, in the younger specimen, but divided into four oral lobes in older ones.

2. The radiating chymiferous tubes, which may be traced from the base of the manubrium for a short distance towards the free edge of the umbrella.

3. The flattened discoidal inverted umbrella.

4. The marginal tentacles. These vary in number, according to the species, but they are always arranged equidistantly around the entire circumference of the umbrella. There is always one, which may be called the radial tentacle (Fig. 15, *F*, 1) in the plane of each chymiferous tube, and another, which may be called the median interradial tentacle (Fig. 15, *F*, 2) midway between each two radial tentacles. In the species figured there are always two, and occasionally three between each radial tentacle and the nearest median tentacle.

5. The *otocysts*. Eight small transparent spherical vesicles, situated upon the oral faces of the bases of the eight tentacles adjacent to the four median tentacles.

6. Examine larger specimens, which may usually be obtained in abundance by dipping at the surface of the ocean on calm evenings, and notice: —

a. The very numerous marginal tentacles.

b. The four deeply cleft oral lobes.

c. The four rounded reproductive organs which project, beyond the outline of the sub-umbrella, one near the middle of each radiating chymiferous tube.

III. Kill a specimen with osmic acid, as directed in Section VII., and after staining with picro-carmine, mount it in dilute glycerine, and examine it with a high power — two hundred to five hundred diameters — and notice: —

a. The ab-oral surface.

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1. The ab-oral surface of the umbrella is covered by large, flat, nucleated cells (Fig. 26, *a*) which are quite

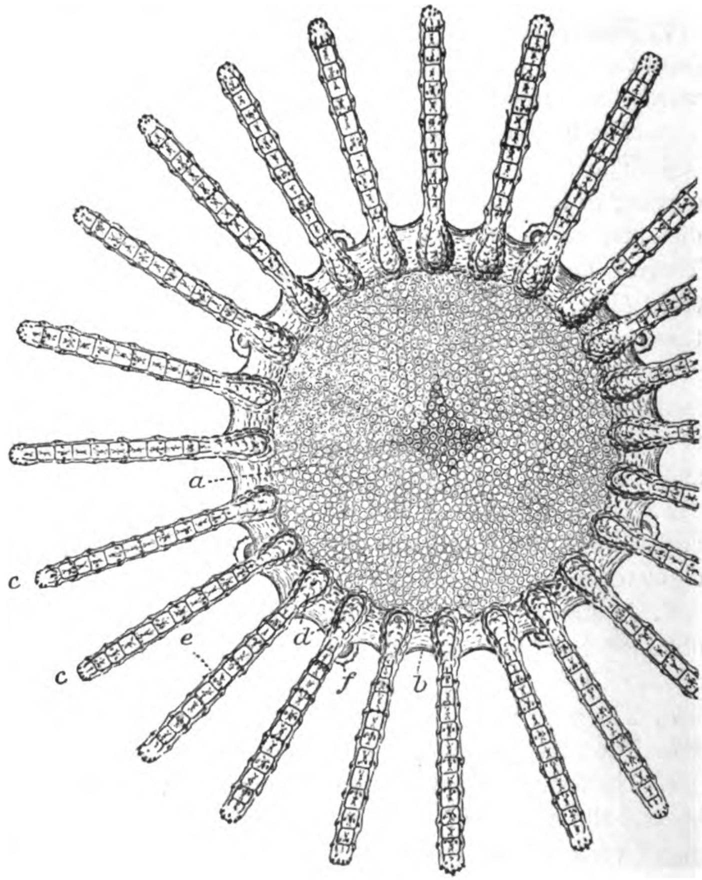

FIG. 26.

FIG. 26. — Ab-oral surface of a young medusa of Eucope, about twelve hours after its escape from the reproductive calycle; from an osmic acid specimen, magnified about two hundred diameters. (Drawn from nature by W. K. Brooks.)

a. Upper surface of umbrella. *b.* Edge of umbrella. *c.* Tentacles. *d.* Enlarged inner side of tentacles. *e.* Shafts of tentacles. *f.* Otocysts.

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distinct in a young specimen, although in an old specimen it is difficult to make out any thing more than their nuclei.

2. Around the circumference of the umbrella there is usually a prominent ridge (Fig. 26, *b*) produced by the folding back of the tentacles.

3. The marginal tentacles (Fig. 26, *c*) are rather sharply divided into an enlarged broad bulb (Fig. 26, *d*) and a more slender cylindrical, slightly tapering shaft, *e*. In the shaft notice: —

(i.) The very thin layer of ectoderm, which is thickened at intervals to form annulations which are filled with large nematocysts.

(ii.) The longitudinal muscular fibres which lie underneath the ectoderm.

(iii.) The transparent supporting layer.

(iv.) The solid axis of large endoderm cells.

4. In the bulb at the base of the tentacle, notice: —

1. The thickened layer of large prominent rounded ectoderm cells.

2. A large central endoderm cell.

b. The sub-umbrellar surface (Fig. 27).

1. The vase-shaped manubrium (Fig. 27, *a*) with a wide opening, the margins of which are divided into four lobes.

(i.) The line of nematocysts which fringes the mouth.

(ii.) The polygonal ectoderm cells which cover the manubrium.

2. A nearly square stomach-chamber (Fig. 27, *b*) which lies in the centre of the sub-umbrella, and is separated by a somewhat contracted neck from the cavity of the manubrium.

3. The four radiating chymiferous tubes (Fig. 27, *c*)

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which run off from the four corners of the stomach towards the edge of the umbrella. These are very difficult

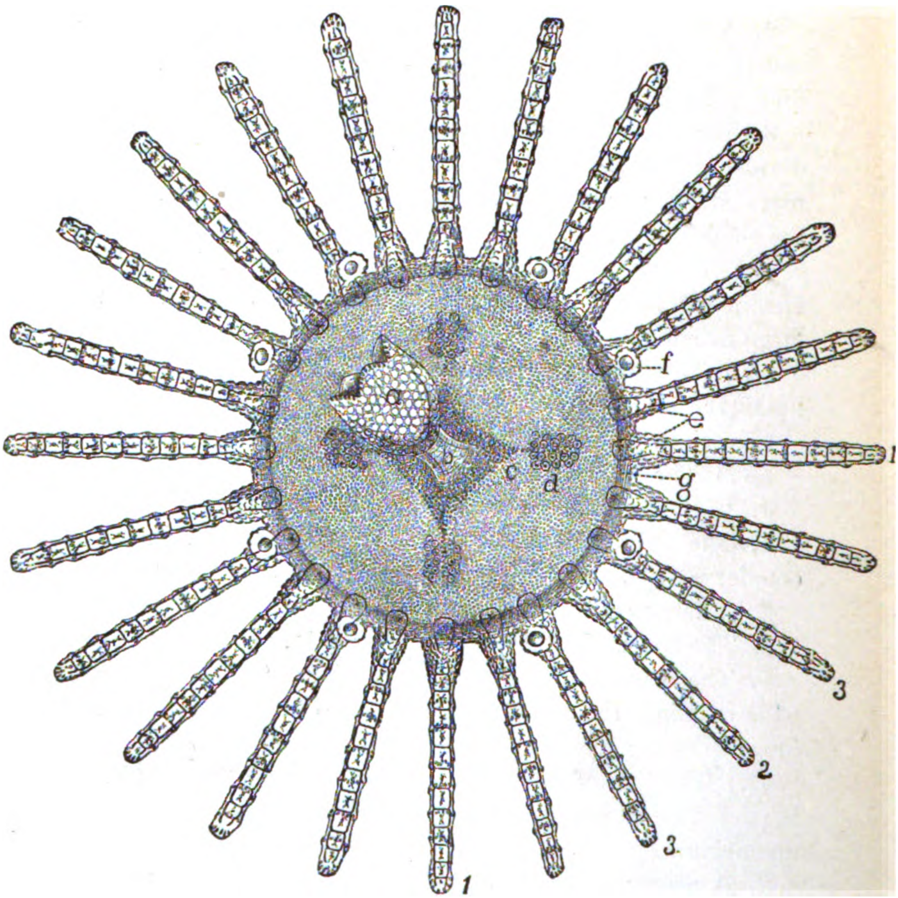

FIG. 27.

FIG. 27. — Oral surface of the same medusa. (Drawn from nature by W. K. Brooks.)

a. Manubrium. *b*. Neck of manubrium. *c*. Radiating chymiferous tubes. *d*. Reproductive organs. *e*. Enlarged bases of tentacles. *f*. Otocysts. *g*. Velum. *1*. Radial tentacles. *2*. Median inter-radial tentacles. *3*. Tentacles which carry otocysts.

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to trace in a young specimen, but more distinct in old ones. The circular chymiferous tube is so small that it can only be seen at all under the most favorable circumstances.

4. The reproductive organs (Fig. 27, *d*) on the lines of the radiating tubes, about half-way between the centre and edge of the umbrella.

5. The small epithelial cells which cover the surface of the sub-umbrella.

6. The velum (Fig. 27, *g*) is very narrow, and is usually stretched over the bases of the marginal tentacles.

1. Notice the small, flat, epithelial cells which cover it, and pass, by a gradual transition, into the rounded ectoderm cells which cover the bases of the tentacles.

7. The auditory organs (Fig. 27, *f*) consist of a nearly spherical capsule, attached to the outer surface of the velum close to the base of a tentacle, and containing a central highly refractive, spherical *otolith.*

IV. Examine one of the auditory organs with a high power — five or six hundred diameters — and notice: —

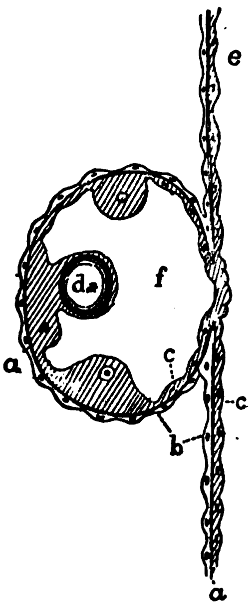

FIG. 28.

FIG. 28. — Otocysts of Euchilota ventricularis, magnified four hundred diameters; from an osmic acid specimen. (Drawn from nature by W. K. Brooks.)

a. Supporting layer. *b.* Outer layer of epithelium. *c.* Inner layer of epithelium. *d.* Otolith. *e.* Velum. *f.* Cavity of Otocyst.

a. The capsule (Fig. 28). This consists of three layers.

1. A very delicate supporting layer (*a*).

2. An outer layer of cells (*b*), continuous with the ectoderm cells of the outer surface of the velum.

3. An inner layer of cells (*c*), continuous with the ectoderm cells of the inner surface of the velum.

b. The otolith (*d*) is surrounded by a delicate layer of protoplasm, by which it is attached to the inner surface of the capsule.

c. Four or five fine *sensory* hairs project from the wall of the capsule towards the otolith.

IX. STRUCTURE OF THE STARFISH.

(*Asteracantheon berylinus.*)

THE HARD PARTS.

SPECIMENS of the common starfish may be found in abundance at low tide at almost any point on our northern coast, although on the more sandy southern coast it may be necessary to dredge for them in deep water. The ordinary oyster-dredge may be used, and specimens can usually be obtained by dredging upon oyster-beds. Some should be preserved in alcohol, and some dry. Those which are to be kept in alcohol should be slit with the point of a sharp knife along the upper surfaces of the rays in order to allow the alcohol to penetrate them, and they should then be placed in seventy-five per cent alcohol. This should be poured off and renewed within a week or less, and replaced by fresh alcohol.

The specimens which are to be dried should be placed, alive, in a flat-bottomed dish of warm fresh water, and left for ten or fifteen minutes. They should then be laid, flat, in enough seventy-five per cent alcohol to cover them, and in about an hour taken out and dried in the sun, or

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by a fire, for about twelve hours. The dried specimens should be used to study the hard parts, and the alcoholic or fresh specimens for the internal structure.

1. In a dried specimen, notice : —

a. The central pentagonal disc, from which radiate five arms, or rays.

b. The nearly flat *actinal* or oral surface.

c. The more convex ab-actinal or ab-oral surface.

d. Upon the oral surface, notice : —

1. The central pentagonal *mouth*.

2. The five clusters of spines, or *mouth papillæ*, which surround and project over the opening.

3. Five grooves or furrows, the *ambulacral* furrows, which radiate from the sides of the mouth along the oral surfaces of the rays to their tips. The furrows are deepest and widest at their central ends, and decrease in size towards the tips of the rays.

e. Make a sketch of the oral surface, showing these points.

f. On the ab-oral surface, notice : —

1. The *integument*, or *perisoma*, made up of an irregular network of calcareous ossicles carrying short blunt spines. The spaces between the ossicles are filled by a soft flexible membrane. Along the middle of the ab-oral surface of each ray the spines form an indefinite line.

2. Near one end of the central pentagonal disc, and opposite an *interradius*, or point of meeting of two rays, notice a white, circular, raised tubercle, the *madreporic body*. When examined with a lens its surface is seen to be marked by fine undulating radiating lines, which give to it the appearance of a piece of madrepore coral.

3. The ray which joins the disc on the side opposite the madreporic body is the *anterior ray*.

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4. The two rays between the bases of which the madreporic body is placed form the *bivium*.

5. The anterior ray, together with one on each side of it, make up the *trivium*.

6. Notice that, while a line drawn through the anterior ray and prolonged across the disc would pass through the madreporic body and divide the animal into symmetrical halves, this would not be true of a line through any other ray.

7. Make a sketch, showing these points.

g, Examine a portion of the ab-oral surface with a lens, and notice the *pedicellariæ;* small stony pincer-like structures, which are scattered over the spaces between the ossicles, and are also found around the bases of the spines. Each pedicellaria consists of a short stem and a pair of movable jaws.

h. With a sharp knife cut off one of the rays near its union with the disc, and examining the cut surface, notice: —

1. The *ambulacral ossicles;* two long slender plates which occupy the centre of the oral surface, and form the roof of the ambulacral furrow. Their lower ends are widely separated, but the plates incline towards each other, and their upper, slightly enlarged ends, meet upon the median line of the ray, above the ambulacral furrow.

2. The upper part of the ambulacral furrow is separated from the lower open portion by a horizontal membraneous partition, which may usually be found in a dried specimen, running across from one ambulacral ossicle to the other just below the point where they meet. The part thus shut off contains the *radiating ambulacral*, or *water-tube*.

4. From the lower end of each ambulacral ossicle a

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horizontal plate, the *inter-ambulacral ossicle*, runs outwards and downwards, and forms part of the outer skeleton of the ray. On the lower or outer surface of each inter-ambulacral ossicle two slender spines are articulated by movable joints at their bases.

4. Running outwards and upwards from the outer ends of the inter-ambulacral ossicles are much larger and thicker plates, each of which carries three or four thick club-shaped movable spines. Each of these plates articulates with several (three or four) of the inter-ambulacral plates.

5. The remainder of the wall of the ray is made up of a membrane which contains an irregular network of ossicles with immovable spines.

i. Make a sketch of the section, showing all these points.

j. Cut off the ab-oral wall of the ray which has been removed, and clean off the dried remains of the soft parts, in order to expose the inner surfaces of the ambulacral plates. The cleaning will be more easily done after the ray has been soaked in warm water long enough to soften it.

1. Notice the *vertebral ridge;* a longitudinal elevation along the middle line of the floor of the ray. The ridge is formed by the union of the upper ends of the ambulacral ossicle, and a shallow longitudinal furrow or suture marks the line where those of opposite sides meet. The vertebral ridge is also marked by hundreds of fine parallel transverse fissures, the sutures between adjacent ambulacral plates. These fissures give the ridge a resemblance to the vertebral column of a vertebrate. In a ray which has been softened in water it will be seen that there is considerable power of motion between the ambulacral plates

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on opposite sides of the ray, and a very slight power of motion between those of the same side.

2. On each side of the ridge is an area marked by two rows of small round openings, and also by fine parallel lines continuous with the transverse furrows of the ridge, and therefore at right angles to the long axis of the ray. This is the area of the ambulacral ossicles. Comparison of the surface view with the sectional view shows that each ossicle is a thin, vertically flattened plate, with its long axis at right angles to the long axis of the ray. It is joined by its inner end to the corresponding ossicle of the other side, and by its flat faces to the plates before and behind it on the same side. In the description of these plates the face nearest the base of the ray will be called the proximal and that nearest the tip the distal; the end nearest the middle of the ray the central, and that farthest from the middle line the peripheral. On each side of each plate there is a perpendicular groove, and the grooves of adjacent plates meet so as to surround tubular spaces which run from the interior of the ray to the lower surface.

The inner ends of these tubes, which are the *ambulacral pores*, are seen on each side of the vertebral ridge. At first sight they seem to be arranged in a double row, but a more careful examination shows that there is only one pore between each pair of ambulacral plates, but that they are alternately central and peripheral, thus forming a "zigzag" instead of a straight line.

Each plate has one groove on each side, one near the peripheral end and one near the central end, and the position of the grooves alternates in adjacent plates, so that if the groove on the distal side of one plate is near the peripheral end, the groove on the proximal side of the next

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plate will be at the same end, and the two will form a tube. The tube between this second plate and the third will, on the contrary, lie at the central end.

3. On the outside of the ambulacral area there is an area marked by a double row of very minute pores; the area of the inter-ambulacral ossicles. These are equal in number and thickness to the ambulacral ossicles, to the outer ends of which they are united.

4. Outside the inter-ambulacral plates there is a row of much larger plates, each of which articulates with three or four inter-ambulacral plates. They are indefinitely cross-shaped, and are united by the long arm of the cross to the inter-ambulacral plates, by the cross-bar to adjacent plates of the same row, and by the top of the cross to the irregular plates of the ab-oral surface. More careful examination shows each to be made up of three distinct ossicles. Between the arms of adjacent plates are large, nearly circular foramina, closed by membrane.

k. Make an enlarged sketch of a small portion of the floor of a ray, showing all these points.

l. Clean and examine the lower or external surface of the same specimen, removing the spines from part of it in order to expose the plates, and notice: —

1. The double row of ambulacral ossicles and their pores.

2. A row of inter-ambulacral ossicles on each side of the ambulacral area.

3. The double row of slender, movable spines, which these ossicles carry.

4. The row of three or four series of thick spines on the cross-shaped plates.

5. Trace this latter row of spines to the tip of the ray, and notice that it passes around the ambulacral and inter-

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ambulacral plates, and unites with the row on the other side of the ray, to form a terminal tuft of spines upon the upper surface of the ray close to the tip.

m. Remove the ab-oral wall from the central disc, and having cleaned away the soft parts, in order to expose the inner surface of its floor, notice: —

1. The pentagonal mouth-opening.

2. The five ambulacral areas converging at the mouth to form the sides of the pentagon.

3. Notice that the alternating arrangement of the ambulacral pores gradually disappears at the proximal end of the ray, so that the last three pores are arranged almost in a straight line.

4. The last pair of ambulacral ossicles are much shorter and thicker than the others, and their proximal edges form the slightly convex sides of the mouth-pentagon. The ambulacral pores of this last pair of ossicles pass directly through the stony matter of the plates.

5. Notice the five *inter-radial partitions* which separate the ambulacral areas of adjacent rays, and are formed by the union of the inter-ambulacral ossicles of one side of one ray to those of the opposite side of the adjacent ray. Each of the inter-radial partitions abuts upon one of the rounded angles of the mouth-pentagon.

6. On each side of the partition there is a perforation somewhat larger than the ambulacral pores; the internal end of the reproductive orifice. Pass a bristle into this tube, and try to find the external opening on the outer surface of the specimen.

n. Make a sketch of the inner surface of the floor of the disc.

o. On the lower external surface of the disc, notice that the rows of inter-ambulacral spines approach each other

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and unite, and project over the mouth, to form the *mouth-papillæ.*

1. Carefully remove these spines, so as to expose the inter-ambulacral plates, and notice that these approach and unite to form the inter-radial partitions.

p. Make a sketch of the lower surface of the disc.

X. THE STRUCTURE OF THE STARFISH.

(*Asteracantheon berylinus.*)

INTERNAL ANATOMY.

I. In an alcoholic or a living specimen notice the following external organs: —

a. The two double rows of tubular feet, or *ambulacra,* which project from the ambulacral furrows, upon the oral surface of each ray.

b. The membraneous *peristome* which fills the space between the mouth and the bases of the rays.

c. The nearly circular mouth. In many specimens a part of the convoluted *stomach* may be found to project out of the mouth.

d. The *ab-oral tentacles:* delicate tubular structures which project from the ab-oral wall of the body, among the spines.

II. Study the manner in which the living animal moves by the use of the ambulacra.

III. The Digestive Organs.

Cut off the tip of one of the rays of the trivium, and notice the cut ends of the *hepatic coeca:* two brown sacculated organs which are attached by a mesenteric membrane to the inner surface of the ab-oral wall of the ray. There is one on each side of the median line, and they

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hang down into the cavity of the ray, which they nearly fill.

With a knife or a pair of strong scissors cut through the body wall for about an inch on each side of the ray, just outside the inter-ambulacral ossicles, taking pains to avoid injuring the soft parts. Lift up the ab-oral wall by its free end, and carefully cut the mesenteric membranes which bind the hepatic coeca to its inner surface. Repeat the cuts in the same way until the roof of the ray has been freed from tip nearly to base. Free the wall of the adjacent ray of the trivium in the same way. Lift up the roof of the disc, and free it from its attachment to the soft parts, nearly as far as the centre. Cut off and remove the integument which has been loosened, thus exposing the internal organs of the two rays and disc. Place the specimen in a shallow, flat-bottomed dish, cover it with water, or water and alcohol, and notice: —

a. The large brown sacculated *hepatic coeca* (Fig. 30, *b*); two in each ray, reaching from the base nearly to the tip. The dilations of the coeca are arranged in pairs, and they hang down into the cavity of the ray.

b. Near the base of the ray the sacculations disappear; the coeca suddenly constrict, and give rise to a pair of delicate membraneous tubes (Fig. 30, *a*), which are attached, like the coeca, to the inner surface of the body-wall, by mesenteric membranes.

The two tubes soon unite to form a common duct, which can be traced into the disc.

c. The proximal ends of these ducts open into a large pentagonal membraneous pouch, the *pyloric sac* of the stomach, which fills nearly the whole of the ab-oral portion of the cavity of the disc, and which is attached to the body-wall along its edges by mesenteric folds. The angles

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of the pentagon are opposite the axes of the rays, and the hepatic ducts open into the ab-oral surface of the sac, a little above the angles.

d. Near the centre of the ab-oral surface of the pyloric sac, notice the short, cone-shaped *intestine*. The anus is so small that it is very difficult to find. It is a little to the left of an imaginary line drawn from the madreporic body to the tip of the anterior ray. A line drawn from the centre of the disc to the angle between the left ray of the bivium and the left ray of the trivium passes through the anus.

e. At or near its union with the pyloric sac the intestine is joined, upon its left side, by a small duct which leads to a light-colored arborescent pouch; the *respiratory tree* (Fig. 30, *g*). This pouch is divided into two sacculi, and these again into small ampullæ. Each of the primary divisions of the organ lies opposite an *inter-radius*, or angle (Fig. 30, *d*) between two rays. One is opposite the inter-radius between the left ray of the trivium and the left ray of the bivium, and the other betweeen the left ray of the trivium and the anterior ray.

f. Radiating from near the centre of the disc are the five extensor muscles (Fig. 30, *n*) of the rays. Normally these are attached to the ab-oral integument. They run from near the centre of the disc to the tip of each ray, giving off, on each side, lateral fibres which are attached to the ab-oral ossicles. By the contraction of these muscles the free ends of the rays may be bent upwards or from side to side.

g. Cut along the sides of one of the unopened rays from base to tip, and also cut through the ab-oral surface of the disc at the base of the ray, and through the hepatic duct, so that the integument, with the organs attached to it, can be turned out from the centre; notice: —

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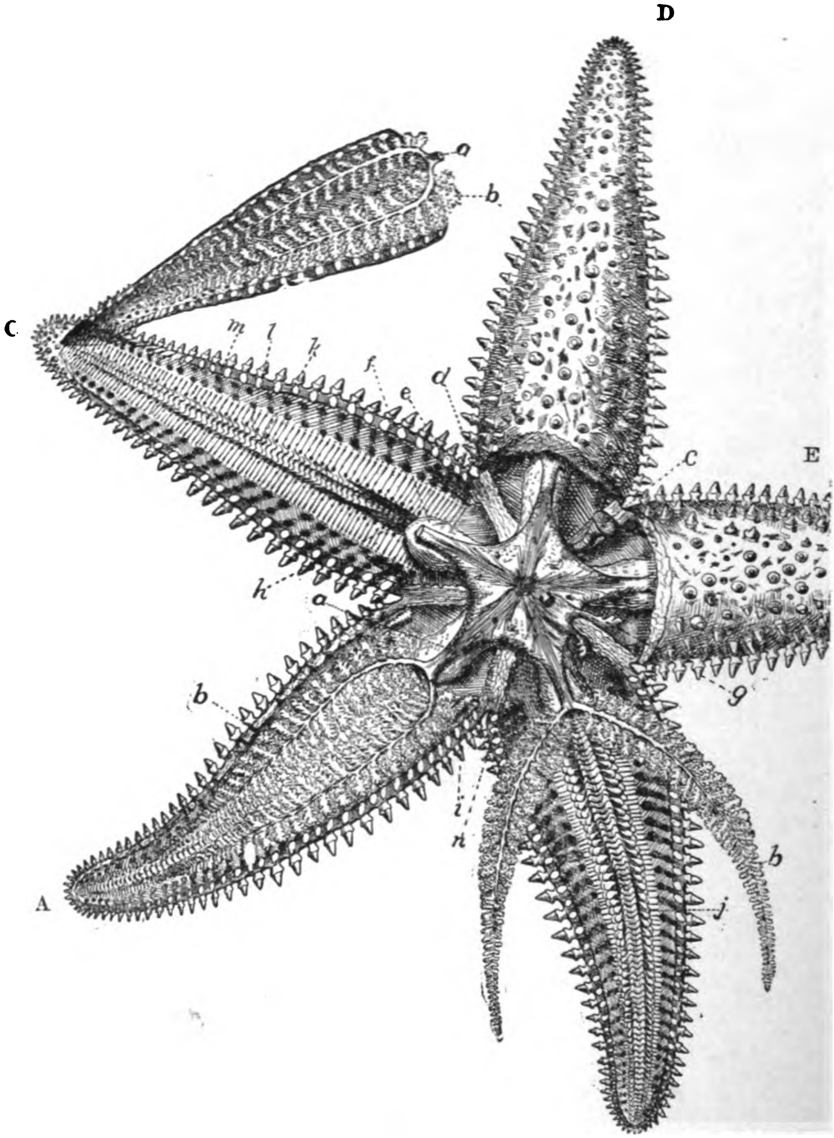

FIG. 30.

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FIG. 30. —Starfish opened from above to show the general anatomy. Drawn from nature by Mr. J. E. Armstrong under the author's direction.

A. The anterior ray, with the integument of the ab-oral surface removed, to show the internal organs in place.

B. The right ray of the trivium, with the hepatic coeca turned out, to show the ambulacral vesicles.

C. The left ray of the trivium, with the ab-oral integument turned back from the base towards the tip, to show the manner in which the hepatic coeca are attached to its inner surface.

D. The left ray of the bivium, unopened.

E. The right ray of the bivium.

a. Duct from hepatic coeca to stomach. *b*. Hepatic coeca. *c*. Madreporic body. *d*. Inter-radial partition. *i*. Reproductive organs. (These were very small in the specimen which was drawn, as it had recently laid its eggs. Just before the breeding season, they are very large and extend nearly to the tips of the rays.)

f. Cardiac pouch of stomach. *g*. Respiratory tree. *h*. Retractor muscles of cardiac pouch of stomach. *e*. Integument. *j*. Ampullæ. *k*. Vertebral ridge. *l*. Ambulacral plates. *m*. Inter-ambulacral plates. *n*. Extensor muscles of rays.

1. The manner in which the hepatic coeca are attached to the integument, by mesenteries.

2. The extensor muscle, running along the median line, between the coeca.

h. Remove the coeca from the adjacent rays by cutting their ducts, close to the pyloric sac. Under each angle of the latter, and therefore opposite the axis of each ray, the stomach will now be seen to project towards or into the cavity of the ray, thus forming a deeply-folded *cardiac pouch* (Fig. 30, *f*).

The five cardiac pouches, together with the central tube into which they open, make up the eversable portion of the digestive tract. An alcoholic specimen may occasionally be found in which these portions of the digestive tract protrude from the mouth; and a living specimen may sometimes be captured with its stomach wrapped

around the shell of a mollusc too large to be taken into the mouth. After eversion these pouches are drawn back into the body by five sets of *stomach retractor muscles* (Fig. 30, *h*). These run out for a short distance into each ray, and are attached to the sides of the vertebral ridge.

i. Cut the muscular attachments of one of the pouches, and raising it up, notice: —

1. The *œsophagus*, a short, cylindrical, longitudinally plicated tube.

2. The *peristome*, or membrane between the outer end of the œsophagus and the edge of the mouth-pentagon.

j. Make a sketch to show as many of these points as possible, and indicate the relation between the various regions of the digestive tract, and the axis of the rays.

k. Make also a diagram of a side view of the digestive organs.

l. Open the pyloric sac of the intestine and notice the valvular folds which guard the opening of the intestine.

IV. The Reproductive Organs.

Remove the digestive organs by cutting the retractor muscles and the œsophagus. Notice the inter-radial septa (Fig. 30, *d*) formed by the union of the inter-ambulacral plates of adjacent rays. Notice the membraneous folds which form the inner or free edges of these partitions. In the proximal end of the cavity of each ray, between the vertebral ridge and the inter-radial partitions are the light-colored *reproductive organs* (Fig. 30, *i*).

There are two of these organs in each ray, and their ducts may be traced into the sides of the inter-radial partitions.

V. The *Ambulacral* or *Water Vascular* System.

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The various organs which compose this system are now exposed. They are: —

a. The *madreporic body* (Fig. 30, *c*); situated upon the ab-oral surface of the inter-radius of the bivium.

b. The *stone canal* (Fig. 31, *c*); a calcareous tube which passes along the free central edge of the inter-radial partition from the stone canal to a point upon the oral surface within the mouth-pentagon. The course of the canal is like the letter S.

c. The *ambulacral vesicles*, or *ampullæ* (Fig. 30, *j*); a double row of small white globular vesicles, with muscular walls, on the inner surface of the ambulacral area, on each side of the vertebral ridge. The lower side of each vesicle gives rise to a tube which passes into one of the ambulacral pores, between the ambulacral ossicles.

d. The *Polian vesicles;* ten muscular sacculi, somewhat larger than the ordinary ambulacral vesicles, and situated upon the ten ambulacral plates which form the sides of the mouth-pentagon.

e. The *ambulacra*, or feet, which are arranged on the lower surface in four rows in the ambulacral furrow, along the oral surface of each ray. If one of the ambulacra be pulled off and carefully examined, its upper end will be found to be prolonged to form a small tube which passes through one of the ambulacral pores to connect with an ambulacral vesicle.

f. Pull off the feet from a portion of one of the rays with a pair of fine-pointed forceps, and notice the *radial water-tube*, a small longitudinal vessel, which runs along the middle of the lower surface of each ray at the top of the ambulacral furrow.

g. Carefully remove the spines which project from the angles of the mouth-pentagon, and notice the circum-oral

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water-tube running around the mouth, just inside the mouth-pentagon. Trace one of the radiating tubes to the point of union with the circum-oral tube.

h. Examining the inside of the specimen, notice that the stone-canal also joins the circum-oral tube.

i. The *racemose vesicles;* nine small sacculated diverticula, which project inwards from the circum-oral water-tube opposite all the ambulacral areas except the one nearest the stone-canal.

j. Make a diagram of the water vascular system.

k. Cut off the top of a ray of a living specimen, and placing the animal in a tub of fresh sea-water, notice, after it has recovered from the operation, the manner in which the ambulacral vesicles inside the ray contract and cause the protrusion of the corresponding ambulacra, by distending them with the fluid which is thus forced into them.

l. Cut off the tip of a ray from a specimen which has not been opened, and introducing into the radiating water-tube the point of a small injecting syringe, fill the water system with a colored fluid, and notice that the ampullæ, the ambulacra, the radiating and circum-oral water-tubes are all filled. Water which has been colored with a few drops of carmine dissolved in ammonia may be used in making the injection; and if no small injecting-syringe can be procured, the fluid may be blown into the specimen through a glass tube which has been drawn out to a fine point.

VI. The Nervous System.

Examine the lower or outer surface of the circum-oral water-tube of an alcoholic specimen with a lens, and notice a thickened ridge along its outer surface running around the mouth. This ring is the circum-oral nerve-ring.

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Radiating from it are five radial nerves, which lie below the radiating water-tubes, and which may be traced to the tips of the rays, where they will be found to end in small spots of dark-red pigment, the five eye-spots, which are on the odd ambulacra at the ends of the rays.

VII. Dissect out the stone-canal and notice that it lies in a membraneous pouch, the *pericardium*, which is formed by two folds, along the inner edge of the inter-radial partition. Notice that the lower end of the stone-canal connects with the circum-oral water-tube, while its upper end joins the inner surface of the madreporic body.

VIII. Notice the *heart*, a membraneous pouch which runs alongside the stone-canal. In a living specimen the heart may be seen to pulsate, and when removed and examined under the microscope it will be found to be made up of a number of tubular vessels, twisted together. It is very difficult to trace the course of the blood-vessels, except by the examination of microscopic sections along their course; but they lie in large chambers, the peri-hæmal vessels, and these may be injected, through the pericardium, with which they communicate, and when filled with coloring matter, they mark out the course of the true blood-vessels with sufficient exactness. A fresh specimen should, if possible, be used in making the injection. With a large needle drill a hole through the madreporic body, passing obliquely backwards and downwards from in front, so as to strike the pericardium on the lower surface of the posterior end of the madreporic body. Introduce a small canula into the hole, and filling the injecting-syringe with a colored fluid, such as water colored with carmine or indigo, force the fluid, very gently, into the pericardium.

If an injecting-syringe cannot be procured, a glass tube,

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drawn out to a fine point, may be used to blow in the fluid.

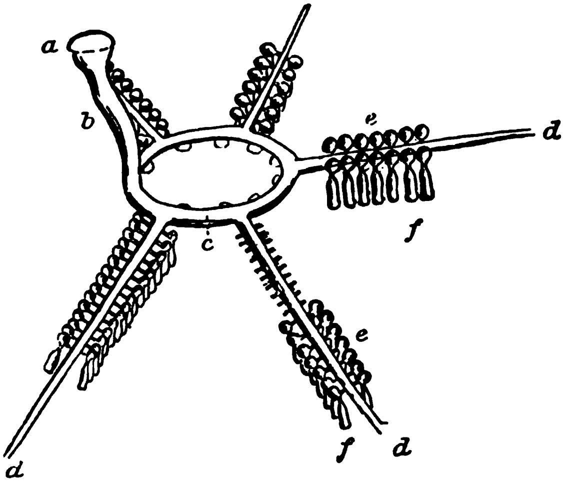

FIG. 31.

FIG. 31. — Diagram of the water system of a starfish.
a. Madreporic body. *b*. Stone-canal. *c*. Circum-oral water-tube. *d*. Radial water-tubes. *e*. Ampullæ. *f*. Ambulacra.

Tracing the course of the peri-hæmal tubes by the colored injection, notice: —

a. A circum-oral peri-hæmal tube, just below the circular water-tube, and connecting with the pericardium.

b. Five radiating peri-hæmal tubes, below the five radiating water-tubes, and sending branches to the ambulacra.

c. A circum-anal peri-hæmal tube, on the inner surface of the integument of the anal surface of the disc. This tube, which is pentagonal and much larger than the one around the mouth, connects with the upper end of the pericardium, and sends branches to the reproductive organs, the hepatic coeca, and the stomach.

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XI. THE MICROSCOPIC STRUCTURE OF THE STARFISH.

The smallest specimens which can be procured should be placed in a quantity of one-half per cent solution of chromic acid for about twelve hours. They should then be transferred to a quantity of one per cent chromic acid, in which they should remain until most of the calcareous matter of the skeleton has been dissolved.

With specimens an inch long or less this should be accomplished in twenty-four hours, but larger specimens may require several days, and in this case the chromic acid should be renewed every day.

When decalcified the specimens should be placed in eighty per cent alcohol for twenty-four hours, and they may then be preserved in ninety per cent or ninety-five per cent alcohol until they are to be examined.

I. Cut off one of the arms, stain and mount it as directed in Section VII., and cut a number of transverse sections.

Examining it with a magnifying power of from twenty-five to fifty diameters, notice: —

a. The remains of the calcareous ossicles (Fig. 32, *b*, *p*, and *q*) imbedded in the integument. They will probably retain enough of their calcareous matter to show that they are formed of a network of calcareous rods or spicules arranged in rows pretty nearly concentric with the outer surface.

b. Notice that the spines (Fig. 32, *g*) of the ab-oral surface are continuous with the ab-oral ossicles.

1. Around the bases of these spines notice the pedicellariæ (*f*), made up of a shaft and two blades. Notice

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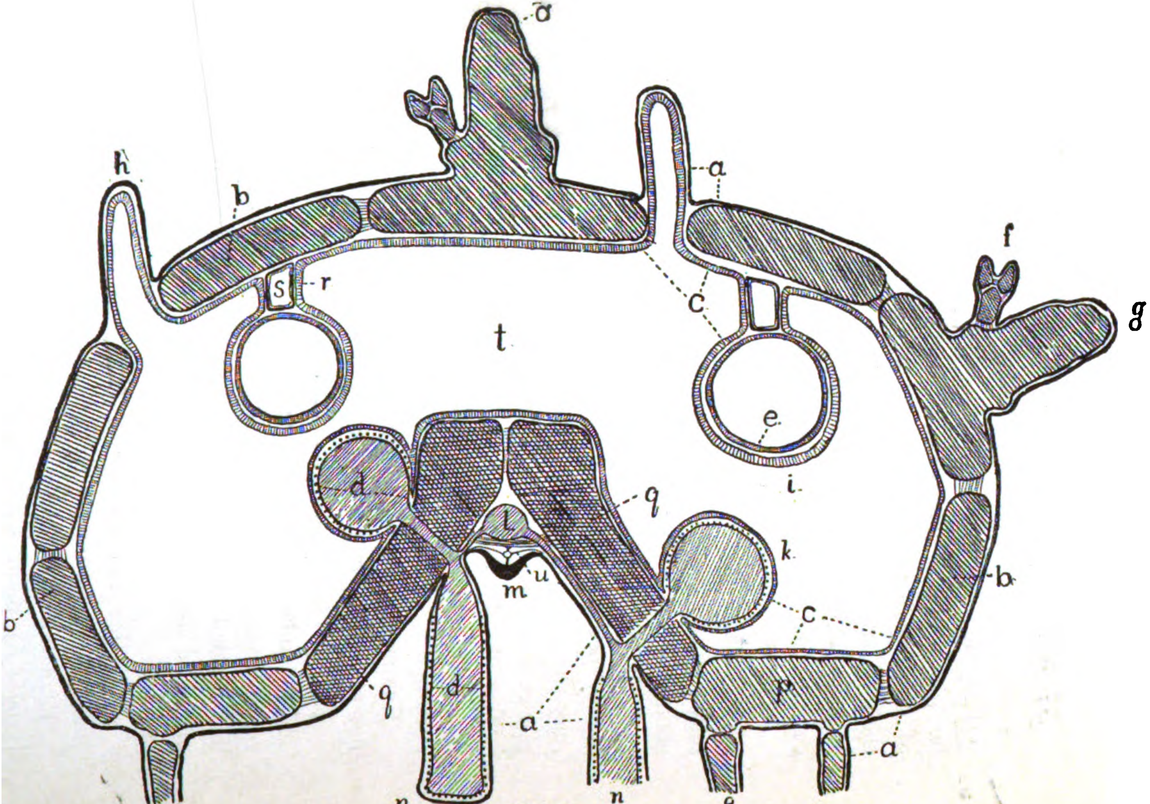

FIG. 32.

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Fig. 32. — Diagram of the transverse section of the ray of a starfish.

a. **The layer of epithelium which invests the outer surface.** ***b.*** **The ossicles of the ab-oral surface.** ***c.*** **The layer of epithelium which lines the perivisceral cavity.** ***d.*** **The layer of epithelium which lines the water system.** ***e.*** **The epithelial lining of the digestive tract.** ***f.*** **Pedicellariæ.** ***g.*** **Spines of ab-oral surface.** ***h.*** **Ab-oral tentacles.** ***i.*** **Hepatic-coeca.** ***k.*** **Ambulacral vesicles.** ***l.*** **Radiating water-tube.** ***m.*** **Radiating nerve.** ***n.*** **The ambulacra.** ***o.*** **Movable spines, carried by the inter-ambulacral ossicles.** ***p.*** **Inter-ambulacral ossicles.** ***q.*** **Ambulacral ossicles.** ***r.*** **Mesenteries.** ***s.*** **Their inner spaces.** ***t.*** **Perivisceral cavity.** ***u.*** **Peri-hæmal spaces.**

the joints between these parts, and the muscular fibres which move them.

c. Notice that the spines (Fig. 32, *o*) which are carried by the inter-ambulacral ossicles (*p*) are furnished with a movable joint.

d. The ab-oral tentacles (*h*) which project through the spaces between the ossicles, and open into the perivisceral cavity (*t*).

e. The layer of epithelial cells, which covers the outer surface of the body, and which is represented in the diagram by the heavy line *a*. It covers the pedicellariæ and the spines, and forms the outer surface of the wall of the ab-oral tentacles.

f. The layer of epithelium which lines the perivisceral cavity, and which is represented by the shaded line *c*. This layer runs into and lines the ab-oral tentacles, and is reflected out so as to cover all the organs which project into the perivisceral cavity.

g. Between this layer and the inner surface of the ab-oral ossicles, a layer of narrow spaces (not shown in the diagram), lined by another layer of epithelium. In a transverse section these spaces appear as narrow slits.

h. The cross-sections of the hepatic coeca (*i*) suspended to the body wall by the mesenteries.

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1. Notice that the layer of epithelium which forms the outer surface of the coeca passes down the mesenteries at *r*, and is continuous with that which lines the body wall.

2. The coeca are lined by another layer (*e*).

3. Notice that each mesentery is double, and encloses a space which is lined by another layer of epithelium. If a dissected specimen be examined, this space (*s*) will be found to open into the perivisceral cavity at the base of the arm, where the coeca give rise to their ducts. The lining epithelium is therefore a continuation of the layer (*c*).

i. Notice the cross section of the radiating water-tube (*l*), in the angle between the two ambulacral plates (*q*).

1. Notice the small tubes which connect this tube with the ambulacra.

2. Notice the tube which passes through the ambulacral pore, between the ambulacral plates, and connects the ambulacral vesicle (*k*) with the foot (*n*).

3. The ambulacral vesicle is made up of three layers: —

(i.) A lining epithelium (*d*) continuous with the lining of the water-tube and foot.

(ii.) An outer layer continuous with that which lines the perivisceral cavity.

(iii.) A layer of muscular fibres between the two.

4. Notice that the foot (*n*) consists of three similar layers, but the outer one is continuous with the layer (*a*) which invests the outer surface of the ray.

j. Notice that the layer (*a*) is greatly thickened on the middle line of the ray under the water-tube, to form the radiating nerve (*m*).

k. Between this and the water-tube there is a space (*u*)

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divided into two by a median vertical partition: this space is the radiating *peri-hæmal* canal.

l. In the partition notice the cut sections of one or two small tubes, the radial blood-tubes.

m. Notice the muscular fibres which connect the various ossicles with each other.

1. Note especially a muscle which runs across the angle between the ambulacral plates, and separates the water-tube from the peri-hæmal tube.

n. Cut as thin a section as possible through the organs in the angle of the ambulacral furrow, and examine it with a higher power, — one hundred to two hundred and fifty diameters, — noticing: —

1. The remains of the ambulacral plates (Fig. 33, *a m*) arching over the ambulacral furrow.

2. The cross section of the radiating water-tube (*r w*) in the angle between the ambulacral plates. If the section passes through one of the small tubes which run off to the ambulacra, notice that the layer of epithelium which lines the large tube also lines the small ones.

3. The muscular band (*m*) which runs from one ambulacral plate to the opposite one underneath the water-tube.

4. Underneath this muscle notice a space (*c*) divided by a vertical partition (*k*) into two. This space is the *radial peri-hæmal tube.* Notice that the layer of epithelium which lines it is very thin above and on the partition, but thickened below, so as to form a pair of opaque granular pads (*l*). As this structure runs along the whole length of the ray, it is actually not a pad, but a long flattened band. According to some investigators, it is to be regarded as constituting the nerve-fibre of the ray; and if this is tne true view, it will be seen that there are a pair of radiating nerve-fibres for each ray.

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5. In the partition (k) which divides the peri-hæmal chamber into two, notice the cut ends of two or three irregular tubes (d). These are the true radial blood-vessels.

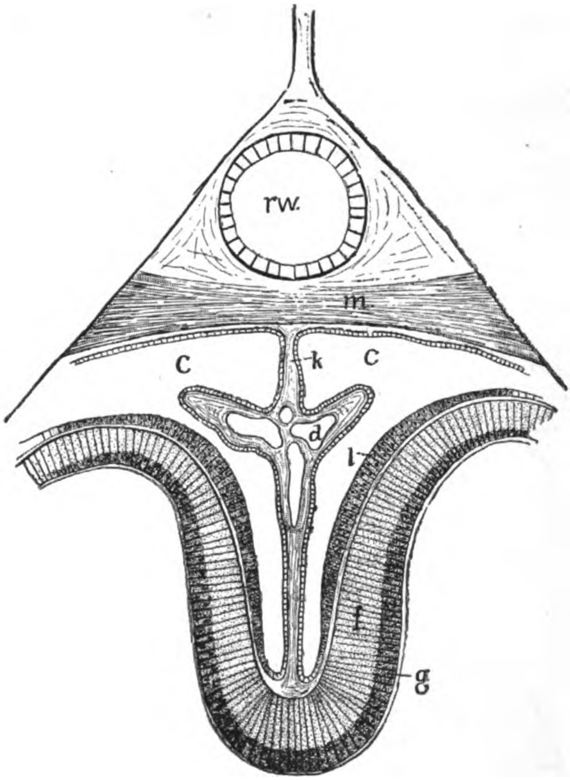

FIG. 33.

FIG. 33. — Transverse section of the ambulacral furrow of the ray of a starfish, magnified about one hundred and fifty diameters.

a m. Ambulacral plates. *r w.* Radiating water-tube. *m.* Ambulacral muscle. *c.* Radiating peri-hæmal canal. *k.* Its median vertical partition. *l.* Thickened band formed by the epithelium of its floor; the nerve, according to Lange. *d.* Radiating blood-vessels. *f.* Inner fibrous layer of the surface epithelium; the nerve, according to Ludwig. *g.* Outer pigmented layer.

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6. The epithelium of the outer surface (*g*) of the middle of the ray is greatly thickened, and is generally regarded as the true nerve of the ray. It is divided into two sharply defined layers.

1. An outer layer (*g*) made up of dark, granular, nucleated cells.

2. An inner layer (*f*) which consists of: —

(i.) Fibres perpendicular to the outer surface, and continuous with the granular cells.

(ii.) Very fine longitudinal fibres, which appear as fine dots in a transverse section (Fig. 33), but as fine parallel lines in a longitudinal section (Figs. 35 and 36, *f*). According to Ludwig, the fine longitudinal fibres are the true nerve-fibres of the ray.

7. Covering the outer surface, notice a very thin, transparent structureless cuticle.

o. Cut a number of vertical sections across the mouth-pentagon, along the line of an inter-radial partition, and mounting them, notice: —

1. The cut surface of the inter-ambulacral plate (Fig. 34, *i a*).

2. The peristome (Fig. 34, *p*).

3. The epithelium (*h*) which lines the perivisceral cavity (*b*).

4. The cut sections of the circum-oral water-tube (*c w*).

5. The muscle (*m*) which connects the ambulacral ossicles of adjacent rays with each other.

6. The circum-oral peri-hæmal vessel, which is divided into an inner chamber (*a*) and an outer one (*c*) by a partition.

7. The circum-oral blood-tube in the partition.

8. The thickened layer of pigmented cells (*l*) in the

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floor of the outer peri-hæmal channel. This is the circum-oral nerve of Lange.

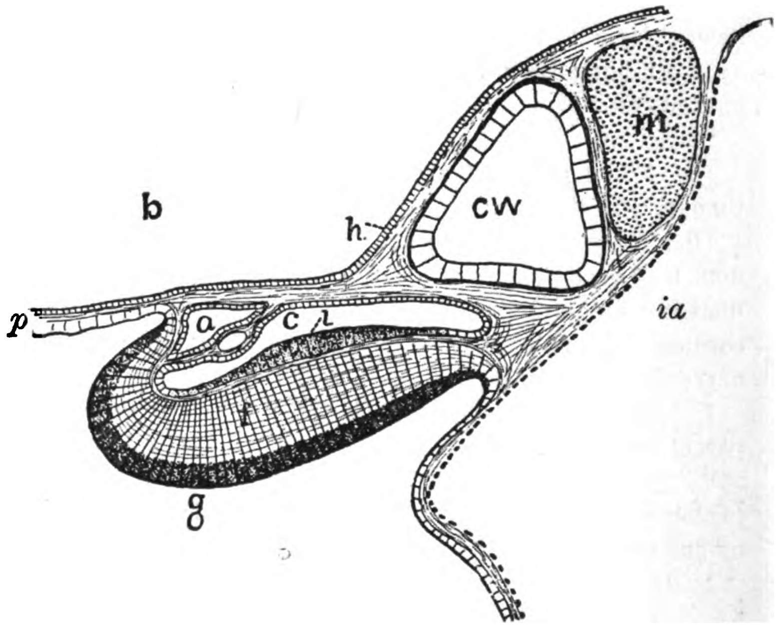

FIG. 34.

FIG. 34.—Vertical section through the mouth-pentagon in the plane of an inter-radius, magnified about one hundred and fifty diameters. (Copied with slight changes from H. Ludwig; Zeit. f. Wiss. Zool. xxx. Taf. VI., Fig. 17.)

i a. Inter-ambulacral ossicle. *m*. Muscle which runs between ambulacral plates of adjacent rays. *c w*. Circum-oral water-tube. *h*. Epithelium of perivisceral cavity. *b*. Perivisceral cavity. *p*. Peristome. *a*. Inner, and *c*. outer division of circum-oral peri-hæmal vessel. *l*. Thickened pad formed by the epithelium of the floor of the outer division of the peri-hæmal vessel. *f*. Fibrous layer of surface epithelium. *g*. Granular layer of the same.

9. The thickened ridge of surface epithelium (*g*) which forms a ring around the mouth between the water-tube (*c w*) and the peristome (*p*). Observe that it is

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similar in structure to the thickening in the ambulacral furrow.

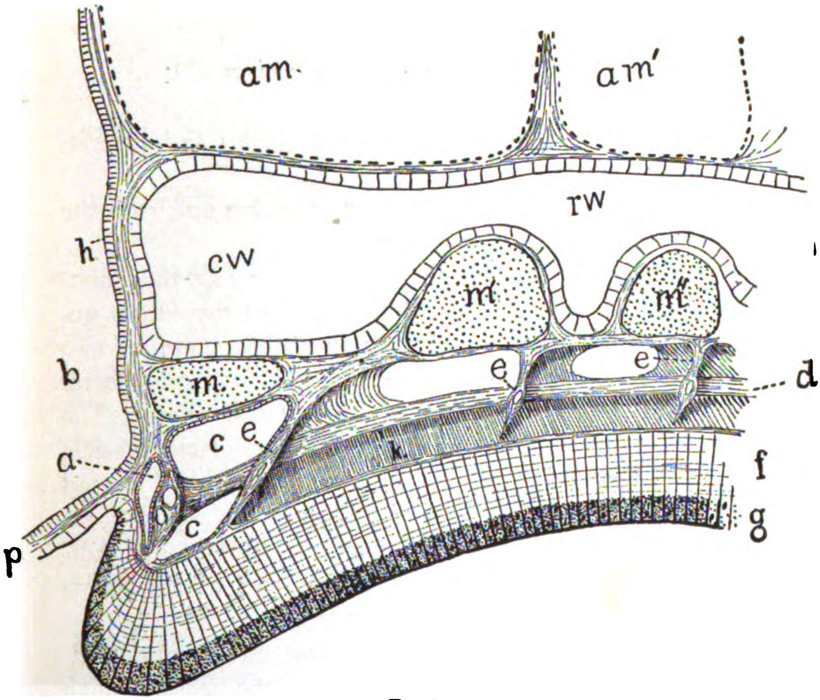

FIG. 35.

FIG. 35. — Diagram of a vertical longitudinal section through the mouth pentagon in the axis of a ray, magnified about one hundred and fifty diameters. (Copied with slight changes from H. Ludwig; Zeit. f. Wiss. Zool. xxx. Taf. VI., Fig. 16.)

a m. The first ambulacral plate. *a m′*. The second ambulacral plate. *c w*. Circum-oral water-tube. *r w*. Radiating water-tube. *m* and *m′*. Muscles which join the pair of plates, *a m*. *m″*. Muscles which join the pair of plates *a m′*. *a*. Inner channel of circum-oral peri-hæmal vessel. *c*. Outer channel of same, at the origin of the radiating peri-hæmal vessel. *d*. Radiating blood-vessel. *k*. The partition which supports it along the middle line of the ray. *e*. Partitions which support the lateral blood-vessels. *b*, *f*, *g*, *h*, and *p*. As in Fig. 84.

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p. Cut a section through the mouth-pentagon, along the axis of a ray, and comparing it with the transverse section of the ray, and with the one through the mouth-pentagon in the plane of an inter-radius, notice: —

1. The ambulacral plates (Fig. 35, *a m*, *a m'*).

2. The peristome (*p*).

3. The layer of epithelium (*h*) which lines the perivisceral cavity (*h*).

4. The radiating water-tube (*r w*) running out from the circum-oral water-tube (*c w*).

5. The muscles (*m*, *m'*, *m''*) which run across the ambulacral furrow, from one ambulacral plate to the other, underneath the water-tube. Notice that while there are two of these muscles (*m* and *m'*) for the first ambulacral plate (*a m*) there is only one for each of the others. The fact that the duct which joins the first ambulacral vesicle to its foot passes through the first ambulacral plate instead of between it and the second has been already noticed. This and the presence of two muscles instead of one indicate that this plate really represents two of the series fused together instead of a single plate.

6. The central channel (*a*) of the circum-oral perihæmal vessel, in the same position as in the section along an inter-radius.

7. The partition which separates this from the outer channel (*c*).

8. The blood-vessels in this partition.

9. The radiating blood-vessel (*d*) which runs from this partition to the tip of the ray.

10. The partition (*k*) which runs along the middle of the ray and supports this vessel between the halves of the radiating peri-hæmal vessel. Notice that the halves of the radiating peri-hæmal vessel communicate with each

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other through a wide opening in the top of this partition under each ambulacral plate.

11. A lateral partition (*e*) under each ambulacral plate carries a blood vessel out to the foot and ambulacral vesicle.

q. Make drawings of the various sections, and trace out the relation which the parts bear to each other in different regions of the body.

XII. THE EXAMINATION OF THE HARD PARTS OF THE SEA-URCHIN.

(*Arbacia punctulata.*)

SEA-URCHINS may usually be obtained in abundance at or a little below low-tide mark in sheltered places among the fronds of algæ. Either the purple urchin (Arbacia) or the greenish brown one (Strongylocentrotus) may be used for laboratory work. The former is more abundant on the southern coast, while the latter is most easily procured on the New-England coast.

The following description has been written from specimens of Arbacia, but the differences between the two are so slight that either form may be used. Specimens should be preserved dry, and also in alcohol.

I. In a specimen which has been dried without removing the spines observe the central spheroidal body, flattened upon one side, and nearly covered by the long, pointed spines. The flattened surface is the *oral* or *actinal*, and a small area free from spines at the opposite part of the body is the *anal* or *ab-actinal area*. On the oral surface, notice: —

a. The membraneous peristome, with small irregular

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calcareous ossicles, forming the wall of the centre of the flattened oral surface.

1. In the centre of the peristome is the *mouth*, surrounded by a thickened lip-like fold of the peristome.

2. The white tips of the five calcareous teeth project from the mouth, and meet at the centre of the oral surface.

3. Examine the peristome with a hand-lens, and notice the pedicellariæ, each consisting of three movable jaws mounted upon a long slender movable calcareous stem.

4. Notice five clusters of mushroom-like ambulacra, or feet, projecting from among the spines around the margin of the peristome. Each foot is made up of: —

(i.) A long cylindrical shaft, which during life could be so lengthened as to reach beyond the tips of the longest spines.

(ii.) A terminal sucker or flattened disc, which contains a flat circular calcareous plate.

5. Five pairs of much larger ambulacra project from the peristome, close to the edge of the mouth.

b. In most dried specimens the ambulacra may be seen to run in five double lines around the spheroidal body, like the meridians upon a globe. They lie among the bases of the spines, and the lines converge towards, but do not reach, a point directly opposite the mouth.

c. Notice that the whole surface of the body except the peristome and a small region opposite it, is studded with long, movable spines.

1. The spines are arranged in ten sets: five double rows between the halves of each double row of ambulacra, and five pyramidal groups between the five double rows.

2. Remove a spine, and after cleaning off the remains of the muscles by which it was moved, examine it with a hand-lens, and notice: —

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(i.) The long, tapering, longitudinally fluted shaft.

(ii.) The flattened, polished, toothed tip.

(iii.) The ridge or column near the base, which served for the attachment of muscles.

(iv.) The highly-polished cup, by which each spine articulates, in a ball and socket joint, with a polished tubercle upon the surface of the shell.

d. The ab-oral area, a small pentagonal region free from spines, opposite the mouth. The centre of this area is made up of four flattened, triangular, movable *anal plates*, which meet in the centre and form the *periproct*.

II. Remove the spines and soft parts, and after macerating the shell for a few days in a strong solution of caustic potash, examine the hard calcareous *corona*, which remains after all the soft parts have been dissolved. Examine first the ab-oral surface, and notice: —

a. The nearly oval space which, in the fresh specimen, is occupied by the four anal plates (Fig. 36, *a*).

b. This space is bounded by the bases of the five triangular ovarian plates (Fig. 36, *b*). These plates form a five-rayed star, with a small perforation, the reproductive opening, at the tip of each ray of the star.

c. One of these plates is a little larger than the other four; rough, and covered with minute perforations. The perforated portion is the *madreporic body*.

d. A small triangular *occular plate* (Fig. 36, *c*) is wedged into the angle between each two ovarian plates. Each occular plate is perforated, near its outer edge, by two very small openings.

(If Strongylocentrotus is used for laboratory work instead of Arbacia, considerable difference will be found in the arrangement of these plates. The periproct contains a great number of small plates in place of four large ones.

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The madreporic body is very conspicuous and its edges are sharply defined. The margin of the periproct is formed by seven plates, the five ovarian and two of the occular plates, and the perforations through the occular plate are much larger than they are in Arbacia, and there is only one in each plate instead of two.)

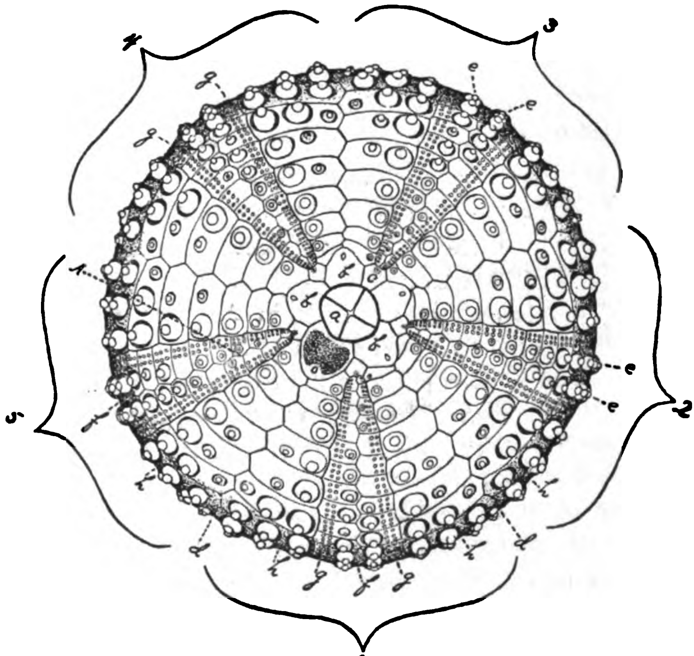

FIG. 36.

FIG. 36. — The ab-oral surface of the corona of Arbacia punctulata, a little enlarged. (Drawn from nature by Mr. H. J. Rice, under the author's direction.)

a. Anal plates. *b.* Ovarian plates. *c.* Occular plates. *d.* Inter-ambulacral sutures. *e.* Tubercles on ambulacral plates. *f.* Ambulacral sutures. *g.* Ambulacral pores. *h.* Tubercles on inter-ambulacral plates. *1*, *2*, *3*, *4*, *5*. The five rays.

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e. Examine the oral surface, and notice: —

1. The large mouth-pentagon which forms nearly the whole oral surface of the corona, and is normally closed by the peristome. The aperture is pretty definitely pentagonal; the angles are concavely rounded, and there is a deep notch in the middle of each side.

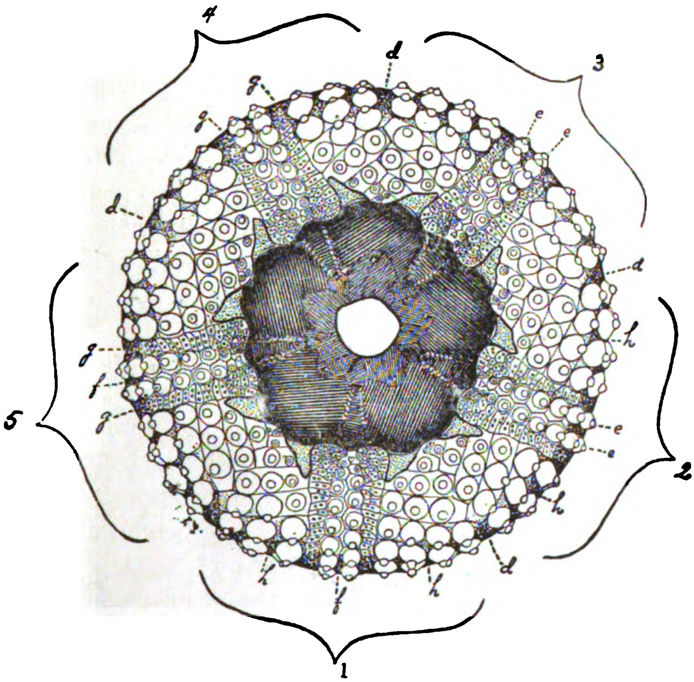

FIG. 37.

FIG. 37. — The oral surface of the corona of Arbacia, a little enlarged. (Drawn from nature by Mr. H. J. Rice, under the author's direction.) The letters and figures of reference are the same as in Fig. 36.

2. The five inter-radial sutures (Figs. 36 and 37, *d*): zigzag lines which run around the corona from the tip of each

ovarian plate to the corresponding angle of the mouth-pentagon. These sutures divide the corona into five areas or rays (Figs. 36 and 37, *1*, *2*, *3*, *4*, *5*), the broad ends of which abut upon the mouth-pentagon and form its sides, as in the starfish, while the tip of each ray lies between two of the ovarian plates, and ends with an occular plate.

f. Mark three of the inter-radial sutures with ink, and notice a second time the points mentioned in *e*.

g. Observe the double row of convex, highly-polished, alternating tubercles for the attachment of spines, along the middle of each ray (Figs. 36 and 37, *e*, *e*, *e*, *e*). Notice that these double rays run from an occular plate to the notch in the middle of the corresponding side of the mouth-pentagon.

h. In the middle of each double row a zigzag *ambulacral suture* (Figs. 36 and 37, *f*, *f*, *f*, *f*). This line also runs from an occular plate to the middle of a side of the mouth-pentagon. It corresponds to the suture along the vertebral ridge of a starfish, and is formed by the meeting of the two sets of ambulacral ossicles which constitute the ambulacral area in the middle of each ray.

i. On each side of the double row of tubercles a double row of ambulacral pores (Figs. 36 and 37, *g*, *g*, *g*, *g*).

j. Outside the ambulacral area a row of inter-ambulacral plates (Figs. 36 and 37, *h*, *h*, *h*, *h*). The outer ends of the inter-ambulacral plates on opposite sides of adjacent rays meet to form the inter-radial suture.

k. Break a corona to pieces by pulling upon opposite edges of the mouth-pentagon. Notice that the plates separate most readily along the inter-radial sutures. Break off some of the inter-ambulacral plates, and notice that they separate from the ambulacral plates along a

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definite, nearly straight suture, just outside the area of ambulacral pores. Each inter-ambulacral plate is nearly rectangular, the sides being longer than the ends. It articulates by its sides with the adjacent inter-ambulacral plates of the same series; by one of its ends with the ambulacral plates of the same ray; and by the other end, which is pointed, with the ends of inter-ambulacral plates of the adjacent ray. On the outer surface of each inter-ambulacral plate are from one to four tubercles for the attachment of spines.

l. Draw a group of inter-ambulacral plates, showing the manner in which they unite with all the plates which touch them.

m. Break up a small portion of an ambulacral area, observing that the plates of the two sides of the ray separate readily along the ambulacral suture, while those on the same side of the ray separate from each other much less readily along sutures which are perpendicular to and opposite the angles of the ambulacral suture. Notice: —

1. That each plate is similar in shape to an inter-ambulacral plate. They are so placed that their flat ends articulate with the flat ends of the inter-ambulacral plates, and their pointed ends with the ambulacral plates of the other half of the ray.

2. On the outer surface of each plate, near the pointed end, a tubercle for the attachment of a spine.

3. The opposite end, — the end farthest from the middle of the ray, — is perforated by three or four pairs of ambulacral pores. The two pores which form a pair are inclined towards each other, so that their external ends are much closer together than their internal ends. The one nearest the middle of the ray serves for the passage of the tube which joins the foot to the radial water-

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tube, the latter being inside the shell of the sea-urchin. The other pore, the one nearest the inter-ambulacral suture, is that through which each foot is connected with its ampulla. The growth of the ambulacral plates shows that each one of them is compound and really consists of as many separate plates as there are pairs of ambulacral pores. With care the lines between these smaller plates may be made out, as shown in Fig. 38, and they remain distinct through life around the mouth-pentagon, as shown in Fig. 37.

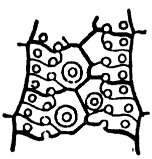

FIG. 38.

FIG. 38.—Five ambulacral plates from the point marked "*A*," in Fig. 36, more enlarged, to show the secondary plates of which they are made up. (Drawn from nature by Mr. H. J. Rice.)

n. Make a sketch of a few ambulacral plates, showing as many of these points as possible.

o. Notice that each occular plate is at the end of a series of ambulacral plates, as in the starfish, while the ovarian plates, like the reproductive orifices of the starfish are opposite the inter-ambulacral sutures.

p. Make a sketch of the ab-oral surface of the corona, showing all the plates and sutures; and indicate in the sketch the limits of the five rays.

q. Make a similar sketch of the oral surface.

r. Notice the five pairs of *auriculæ*, or perpendicular plates, which project upwards from the inner surfaces of the ambulacral plates which form the sides of the mouth-pentagon.

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XIII. THE INTERNAL STRUCTURE OF THE SEA-URCHIN.

(*Arbacia Punctulata.*)

Carefully remove the spines from an alcoholic or a fresh specimen; place it, mouth uppermost, in a shallow pan or a bowl, and pour on enough dilute acid to cover all but the oral surface (two per cent. nitric acid will answer). After it has remained in the acid long enough to remove the calcareous matter from the integument, — from twenty-four to forty-eight hours, — wash it thoroughly with water. Place it in a shallow pan, with enough water, or water and alcohol, to cover it, and cut, with a pair of sharp-pointed scissors, through the integument just outside of and entirely around the periproct, taking care to cut no deeper than the integument. From the edges of this circular incision make five radiating cuts along the lines of the inter-ambulacral sutures down to the oral surface.

I. Turn back the five flaps, and notice the following structures: —

a. The five large sacculated reproductive glands (Fig. 39, *a*), reddish-brown in the female, and gray in the male. They occupy the upper ends of the inter-ambulacral areas, and are attached to the integument in such a way that each would be split into halves if the five radiating incisions were deep enough.

b. On the middle line of the inner surface of each flap notice the radial water tube (Fig. 40, *i*).

c. On each side of this a single row of flattened, leaf-like ampullæ (Fig. 40, *j*).

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d. Turn the periproct over, and notice: —

1. The five genital ducts, which run from the reproductive organs to pass through the pores of the ovarian plates to open on the upper surface.

2. The dark brown intestine (Fig. 39, *d*), opening in the centre of the periproct.

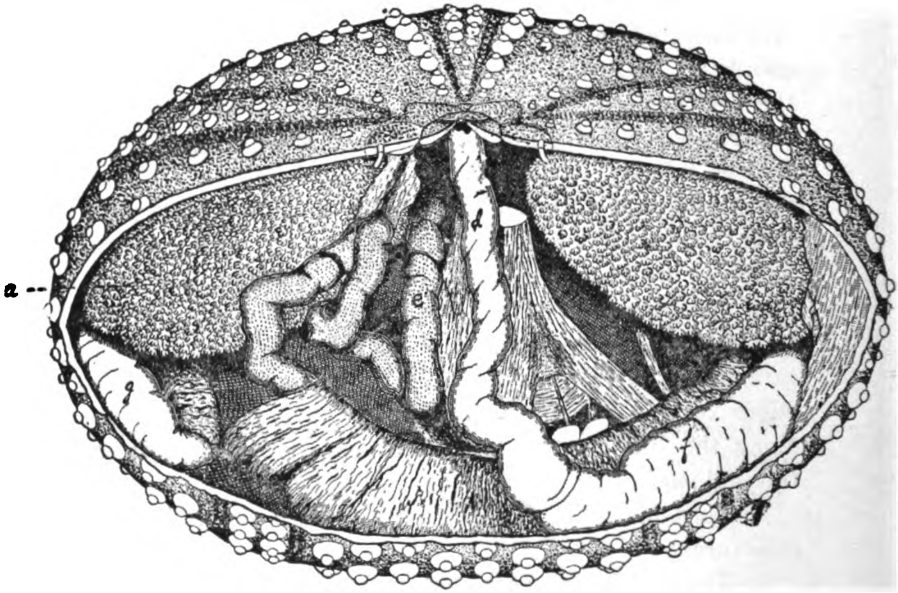

FIG. 39.

FIG. 39. — Side view of Arbacia punctulata, with the spines and part of the corona removed, to show the internal organs. (Drawn from nature by H. J. Rice, under the author's direction.) A little enlarged.

a. Reproductive organs. *d.* Intestine. *e.* Œsophagus. *f.* Pyloric division of stomach. *g.* Cardiac division of intestine.

3. The œsophagus, *e;* a somewhat similar brown tube, which forms a loop close to the anal end of the intestine.

4. From this loop the œsophagus passes into the centre of the upper surface of a large complicated structure,

Aristotle's lantern, which is made up of a great number of calcareous plates, and projects from the peristome into the body cavity.

5. In contact with the wall of the œsophagus, a small membraneous tube, the stone canal (Fig. 40, *a*) runs from the madreporic body across the perivisceral cavity to the lantern.

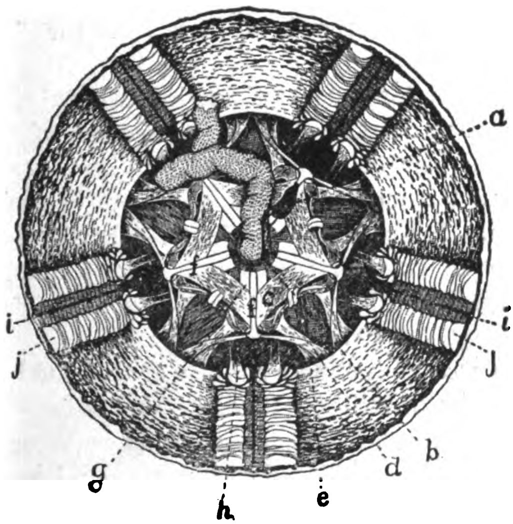

Fig. 40.

Fig. 40.—Internal view of the oral half of the corona of Arbacia punctulata, to show the muscles of the lantern. (Drawn from nature by H. J. Rice, under the author's direction.)

a. Stone canal. *b*. Circular water tube. *c*. Concentrator muscles of lantern. *d*. Tendons of lantern. *e*. Protractor muscles. *f*. Radulæ. *g*. Radii. *h*. Retractor muscles. *i*. Radial water tubes. *j*. Ampullæ.

6. The stone canal joins the circum-oral water tube (Fig. 40, *b*), which surrounds the œsophagus where it enters the lantern.

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7. On the side of the upper end of the stone canal notice a small dark brown corrugated pouch, the heart.

e. Cut the stone canal, and separate the wall of the intestine from the wall of the œsophagus, and turning the periproct to one side, trace the course of the digestive tract, noticing: —

1. The intestine, (Fig. 39, *d*), running downwards from the anus, and passing through one of the reproductive organs, underneath which it joins the "pyloric" chamber of the stomach.

2. This is a long, flat, wrinkled brown tube, *f*, which runs around nearly the whole circumference of the body. Its inner or central edge is free, but its outer edge is attached to the integument on each side of each ambulacral area. Notice the small, lighter-colored vessel which runs along its inner or free edge. After running around the body, it bends down upon itself to join the "cardiac" chamber (Fig. 39, *g*).

3. This also runs almost entirely around the body, but in the opposite direction. Its outer edge is folded or sacculated, and is attached by mesenteric membranes to the integument on each side of each ambulacral area, while its inner margin is free, and bounded by a large, smooth-walled tube, which is sharply distinguished from the outer-sacculated portion. After encircling the body, the cardiac chamber bends upwards to join the œsophagus, *e*.

4. This is a somewhat smaller tube, which makes two abrupt bends upon itself, and then passes up on to the ab-oral surface of the lantern to enter the channel in its centre.

f. Make a drawing, showing as many of these points as possible.

II. Examination of the dentary apparatus and its

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muscles. The dentary apparatus, or lantern, is now exposed, together with its complicated system of muscles, occupying the centre of the oral half of the body cavity. Before examining the muscles the hard parts should be studied, and this may be done to best advantage with a dried specimen. In such a specimen notice: —

a. The points of the five teeth protruding from the mouth.

b. Cut with a sharp knife through the peristome, close to the stony edge of the mouth pentagon; lift up one edge of the peristome and pull the lantern out of the shell. It is made up of a number of calcareous pieces, which are so arranged as to form a cone, with a broad, flat, circular base (Fig. 41, *a*), which is turned towards the anal surface; and an oral apex (Fig. 41, *b*), made up of the tips of the five teeth. The axis of the cone is a tube for the passage of the œsophagus. Pull off the peristome, and the remains of any soft parts which may adhere to the lantern, and in a side view notice: —

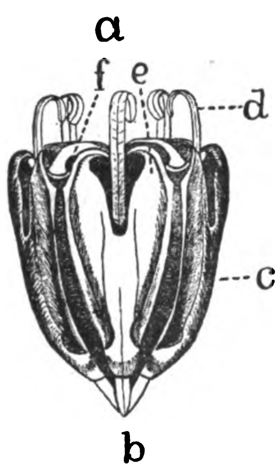

Fig. 41.

Fig. 41. — Side view of the lantern. (Drawn from nature by H. J. Rice.)
a. Upper surface of base. *b*. Apex. *c*. Alveoli. *d*. Teeth. *e*. Epiphyses. *f*. Radulæ.

1. The five triangular pieces or *alveoli* (Figs. 41 and 42, *c*), which carry the teeth. The peripheral surface of each alveolus is nearly an isosceles triangle, with a short base, and two much longer sides. The base is at the top, the acute angles at the bottom, and the long sides of ad-

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jacent alveoli are parallel. The acute angle is truncated, and the tip of the tooth completes the triangle. The base is not a straight line, but a deep, re-entrant angle, which reaches nearly half way to the vertex.

(i.) Along the middle line of the alveolus a straight suture marks the union of the two parts which compose it.

(ii.) Opposite the vertex of the re-entrant angle the inner end of the tooth (*d*) may be seen.

(iii.) The upper or basal angles of the cluster are prolonged to form a pair of horn-like processes (*e*), which lean towards each other and towards the axis. They are immovably joined to the alveoli, although they are in reality distinct pieces, or *epiphyses*, separated from the alveoli by sutures.

2. The dried, dark-colored remains of the concentrator muscles, which bind the parallel faces of adjacent alveoli to each other.

3. Over the points where the basal angles of the five alveoli approach each other, notice the flattened, peripheral ends of five plates, the radii (Figs. 40, *f*, and 41, *g*), which lie on the flat inner end of the lantern.

4. Under the ends of the five radii notice the outer ends of the five radulæ (Fig. 40, *g*), each of which articulates, by a movable joint, to the basal angles of two alveoli.

5. Make a drawing of a side view of the lantern, showing all these points.

6. On the inner or flat surface of the lantern notice:—

(i.) The axial tube for the passage of the œsophagus.

(ii.) The five radulæ, rectangular in a surface view, and with their central ends meeting around the œsophagus. Notice at the outer end of each radula the notches by which it articulates with the alveoli.

(iii.) The five radii running along the middle lines of the

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radulæ, and articulating with them centrally, while their peripheral ends are free.

(iv.) The ten epiphyses, articulating with the ends of the radulæ.

(v.) The free inner ends of the five teeth.

7. Make a drawing showing all these points.

8. Remove one of the alveoli, and in a side view notice: —

(i.). The flat surfaces (Fig. 42, *b*) by which adjacent alveoli face each other.

(ii.) The parallel horizontal ridges for the attachment of the concentrator muscles.

(iii.) The groove or joint along the upper edge, for articulation with the radulæ.

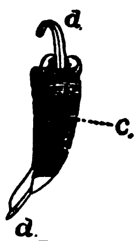

FIG. 42. — Side view of an alveolus. (Drawn from nature by H. J. Rice.)
b. Flat surface of alveolus. *c*. Outer surface. *d*. Tooth.

FIG. 42.

(iv.) The open space between the central edges of the halves of the alveolus.

(v.) The long tooth (Fig. 42, *d*) set into the socket formed by the alveolus. Take out the tooth and notice:—

(*a*.) The exposed pointed cutting edge.

(*b*.) The ridge or keel along the inner surface.

(*c*.) The long, imbedded, growing portion of the tooth.

c. The muscles of the lantern may now be examined in an alcoholic specimen. Notice: —

1. The five transverse muscles (Fig. 40, *c*) which connect the five radii with each other on the inner surface of the lantern.

2. A pair of tendons (Fig. 40, *d*) running outwards and downwards from the outer end of each radius to the inter-ambulacral areas of the inside of the shell.

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3. Between each pair of these a pair of protractor muscles (Fig. 40, *e*) running from the upper angles of each alveolus to the corresponding inter-ambulacral area.

4. Five pairs of retractor muscles (Fig. 40, *h*) running from the auriculæ to the oral ends of the alveoli.

5. The inter-alveolar muscles, running between the faces of adjacent alveoli.

6. Make a sketch of the lantern, with its muscles.

d. Notice the radiating water tubes (Fig. 40, *i*) which pass out from under the outer ends of the radulæ; run down over the outer surfaces of the inter-alveolar muscles, and then pass out between the auriculæ, and run upwards along the inter-ambulacral suture to the ovarian plate. Notice the flat, leaf-like ampullæ upon each side of the water tube.

e. The nervous system. As the nerve ring is situated upon the inner surface of the peristome, between the œsophagus and the tips of the alveoli, it is necessary to carefully cut away one side of the lantern, in order to expose it. This may be done by breaking the alveoli away in small pieces, with a pair of strong scissors. After exposing the nervous system, notice: —

1. The circum-oral nerve ring, a pentagonal ridge around the œsophagus, just inside the tips of the five teeth.

2. The five radiating nerve fibres running along the ambulacral sutures from the angles of the pentagon to the ovarian plates *outside* the water tubes, or between them and the corona.

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XIV. THE EMBRYOLOGY AND METAMORPHOSIS OF ECHINODERMS.

THE eggs of the Echinoderms are especially adapted for examination by a beginner, on account of the simplicity of the early stages; and the student of the elements of morphology can nowhere find more favorable material for studying the more general features of embryology. The eggs of Arbacia are in certain respects unfavorable for the study of the special features of echinoderm embryology, but the ease with which they may be procured and reared, and the fact that the breeding season extends through the whole summer, render it, on the whole, the best form for our purpose.

Those who wish to pay more extended attention to the subject may study the eggs of Strongylocentrotus, in connection with those of Arbacia; for while the opacity of the latter renders the observation of their internal structure very difficult, the eggs of Strongylocentrotus are transparent. The excellent figures, by Alexander Agassiz, of the metamorphosis of Strongylocentrotus, have been reproduced in Agassiz' Seaside Studies, Packard's Life Histories, Balfour's Comparative Embryology, and other text-books; so that the student can readily obtain from them such guidance as he will need for more extended research.

I. The fertilization of the eggs of Arbacia. The spawning season of this species on the southern coast extends from early spring to the end of August, and on the northern coast it probably lasts several weeks longer.

The eggs may be obtained by chopping up the ovaries; or they may usually be obtained after they have been laid.

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In order to obtain them and fertilize them artificially, open a number of fresh specimens by cutting across the middle of the shell horizontally with a strong knife. Notice that the reproductive organs of some of them, the females, are dark brown, while those of others, the males, are milky white. After two or three of each sex have been opened, cut out a small fragment of the ovary of a female, and place it on a glass slide, with a drop of water, and pressing and moving it gently, notice that the minute brown eggs escape into the water. After these have been shaken out of the fragment throw it away, and examine the drop under the microscope with a power of fifty to one hundred diameters, noticing the dark, brownish-red, spherical yolks, with their thick, transparent shells. If the eggs are of uniform size and color, they are probably ripe, and ready for fertilization; but if they vary much in size, and if some are more transparent than others, other specimens should be examined until one is found in which the eggs are more uniform. Place this specimen on one side, where it can be recognized, and keep it until a ripe male is found.

Cut a small fragment from the white testis of a male, and tear it to pieces in a drop of water, and examine, with a power of about one hundred diameters, the white fluid which escapes. It will be found to consist, in great part, of minute granules, which can barely be recognized with this power. These particles, which are the *spermatozoa*, will be seen to be in constant dancing or jerking motion. It is rather difficult for a beginner to determine whether the spermatozoa are fully ripe or not. The best plan is to examine fluid from several males, and to set aside the one in which they are most uniform in size and active in motion.

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Place a drop of fluid from the testis of this male upon a clean slide, cover it with a cover glass, and examining it with a power of two hundred and fifty to five hundred diameters, notice that each spermatozoon consists of a small, highly refractive, rounded "head," and a long, slender, undulating "tail," and is somewhat tadpole-shaped. If, with this power, the spermatozoa appear uniform in size, and if there is little or no fine granular matter scattered among them, the fluid is probably ripe.

Carefully cut out the reproductive organs of the male which has been selected, and placing them in a large watch-crystal, chop them up with a pair of scissors, to facilitate the escape of the spermatozoa. Pick out and throw away the fragments, and pour or wash the milky fluid into a small tumbler or beaker, with about half a pint of fresh sea-water.

Set this aside, and chop up in the same way the ovaries of the female which has been selected. Pick out the fragments, and pour the red fluid into the water which contains the spermatozoa, and having gently stirred it for a minute or two, set it aside to allow the eggs to settle to the bottom.

In about half an hour, carefully pour or siphon off the water, replace it with fresh, and stir for a minute or two. Repeat this process at the end of another half hour, and so on until the water, after the eggs have settled, is clear and transparent. Set it aside where it may have plenty of light, without exposure to the sun. In about twenty-four hours, the larvæ which have hatched will be found swimming close to the surface of the water. Carefully siphon them off, or draw them up with a dipping-tube, and place them in another tumbler of water, in order that they may not be poisoned by the decomposition

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of those eggs which do not hatch. In about twenty-four hours more, place them in a larger tumbler, and fill this up with fresh sea-water, and repeat this every day. After five or six days, it will be best to distribute the larvæ among several small tumblers of water, by picking up a few with a dipping-tube, and placing them in each tumbler. As they grow larger, they may be picked out and placed in a watch-crystal every day while the water is changed.

If specimens can be found in the act of discharging their reproductive elements, there will be no need of dissection. If a number of specimens are placed for a few hours in a large tub of sea-water, some of them may discharge the brown ova and white male fluid from the orifices in the reproductive ossicles. As these reproductive elements settle to the bottom, they may be drawn up through a long dipping-tube, and mixed as above described.

II. Microscopic examination of the segmenting egg.

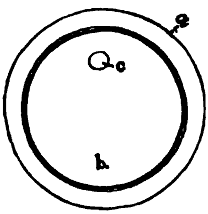

FIG. 43.

FIG. 43.—A newly-laid egg of Arbacia punctulata, magnified about two hundred diameters. (From a sketch by H. Garman.)
a. Eggshell. *b*. Yolk. *c*. Germinative vesicle.

a. The unfertilized egg. When this is examined with the microscope, it is seen to be perfectly spherical (Fig. 43), consisting of an opaque, brownish-red yolk (*b*), surrounded by a thick, transparent shell (*a*). When crushed under a cover glass, the yolk will be found to owe its color to minute reddish granules, or food particles, which fill the transparent protoplasm so completely as to color it uniformly. Near the surface of the yolk, notice a round,

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transparent spot, the germinative vesicle (*c*); rather difficult to detect in the opaque egg of Arbacia, but more distinct in the egg of Strongylocentrotus.

b. A few minutes after the egg has been placed in the male fluid, its surface will be found to be thickly covered with spermatozoa, which are attached to it by their "heads," while their "tails" continue in motion with such activity that they may cause the egg to spin or roll through the water. At about the same time the germinative vesicle ceases to be visible, although the examination of the more transparent eggs of Strongylocentrotus shows that it does not actually disappear, but undergoes important changes. As these cannot be observed in our species, however, they will not be described here.

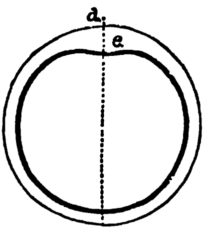

FIG. 44.

FIG. 44. — Egg of Arbacia punctulata, a few minutes after fertilization. (From a sketch by H. Garman.)

d. Principal axis. *e*. Furrow indicating the position of the first cleavage plane.

Soon after the germinative vesicle becomes invisible, the yolk (Fig. 44) becomes slightly notched at a point *e*, upon its periphery, and it is therefore no longer spherical, but divisible into symmetrical halves in the plane (*d*), of Fig. 44. The axis which lies in this plane is now different from any other

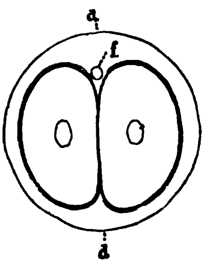

FIG. 45.

FIG. 45. — Egg at the end of the first period of active segmentation. (From a sketch by H. Garman.)

f. Direction cell. *d*. Principal axis.

which can be drawn through the centre of the egg, and is known as the principal axis. In a few minutes more,

the notch (*e*), is much deeper, and a small, transparent body, the "direction-cell" (Fig. 45, *f*), separates from the yolk in the notch. The direction cell takes no part in the development of the embryo, and soon disappears in Arbacia, although, in other animals, it may persist for some time, thus indicating in the embryo the point occupied by the principal axis. That end of the principal axis where the direction cell is situated is known as the germinative pole, while the opposite end is known as the nutritive pole.

The notch deepens rapidly; soon runs entirely through the egg, and divides it, along the principal axis, into two equal and similar masses, the two primary segmentation spherules (Fig. 45). At the same time, a circular, slightly transparent spot, the segmentation nucleus, becomes indistinctly visible in each spherule.

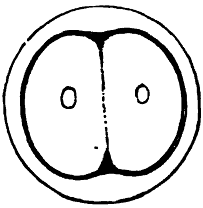

FIG. 46.

FIG. 46. — Egg during the period of rest which follows the first period of segmentation. (From a sketch by H. Garman.)

c. The first division of the egg goes on quite rapidly, but as soon as it is completed, the egg passes into a resting stage; the two spherules flatten against each other, the fissure between them becomes indistinct, as shown in Fig. 46, and the egg remains for some time without change.

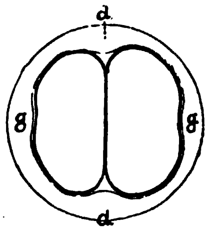

FIG. 47.

FIG. 47. — Egg at the beginning of the second period of segmenting activity.
g. *g*. Beginning of the second cleavage furrow.

d. The next period of activity is initiated by the reap-

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pearance of the distinct furrow between the two spherules. The segmentation nuclei then become invisible (Fig. 47), and traces of a second division make their appearance at right angles to the first, but, like the first, in the plane of the principal axis. Four segmentation nuclei now appear in place of the two, and the egg soon becomes divided into four spherules, as shown in Figs. 48 and 49. The first of these figures gives a polar view, or a view in the line of the principal axis, while the second is a side view, or one at right angles to this axis.

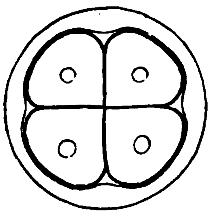

FIG. 48.

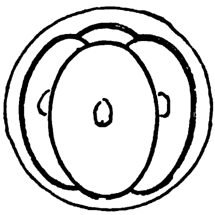

FIG. 49.

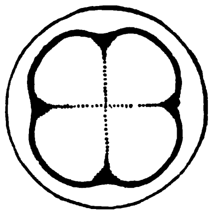

FIG. 50.

FIG. 48. — Egg at the end of the second period of activity, viewed from one end of the principal axis. (From a sketch by H. Garman.)

FIG. 49. — The same egg viewed at right angles to the principal axis. (From a sketch by H. Garman.)

FIG. 50. — An egg during the resting stage which follows the second period of activity, seen from one of the poles of the principal axis. (From a sketch by H. Garman.)

e. The five spherules now flatten against each other, the line between them becomes indistinct, and the egg passes into the resting stage (Fig. 50).

f. The spherules again become distinct, and a plane of division makes its appearance at right angles to the principal axis, and soon divides each of the four into two, so that the egg now consists of eight (Fig. 51).

g. This division is followed by a resting stage, shown in Fig. 52.

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h. During the next stage of activity, each of these eight becomes divided into two, by a cleavage along a plane passing through the principal axis. In a polar view (Fig. 54), eight of the sixteen spherules thus formed are visible, while ten are visible in a side view (Fig. 55).

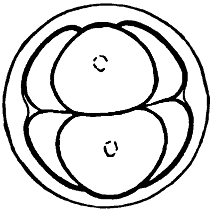
FIG. 51.

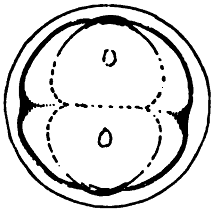
FIG. 52.

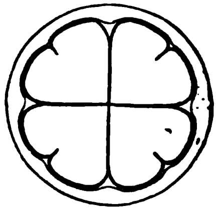
FIG. 53.

FIG. 51. — Side view of an egg at the end of the next period of activity. (From a sketch by H. Garman.)

FIG. 52. — Similar view of the same egg during the next period of rest. (From a sketch by H. Garman.)

FIG. 53. — View of one of the poles of the principal axis of an egg, at the commencement of the next period of activity. (From a sketch by Mr. H. Garman.)

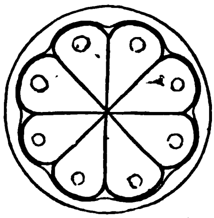
FIG. 54.


FIG. 55.

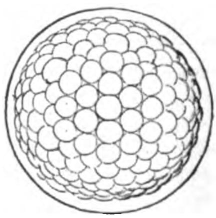
FIG. 56.

FIG. 54. — Similar view of the same egg at the end of the period of activity. (From a sketch by Mr. H. Garman.)

FIG. 55. — Side view of the same egg. (From a sketch by Mr. H. Garman.)

FIG. 56. — Surface view of an egg in an advanced stage of segmentation. (From a sketch by Mr. H. Garman.)

i. Repeated divisions increase the number and diminish the size of the spherules, and in from three to twenty-four

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hours, according to the temperature, the eggs present the appearance shown in Fig. 56. Careful examination, in a good light, will now show that the egg is hollow, and consists of a spherical shell (Fig. 57, *h*), around a central space, or *segmentation cavity*, *i*. The shell consists of a single layer of wedge-shaped spherules or cells, each of which contains a nucleus.

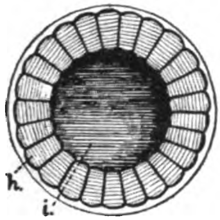

FIG. 57.

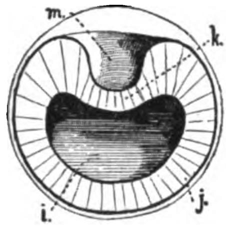

FIG. 58.

FIG. 57. — Diagram of the same egg, seen in section.
h. The single spherical layer of cells. *i*. The segmentation cavity.
FIG. 58. — Diagram of the embryo as seen in section at the beginning of the gastrula stage.
i. Segmentation cavity. *j*. Ectoderm. *k*. Endoderm. *m*. Orifice of invagination.

III. The Gastrula stage. One side of this shell now becomes invaginated, or pushed in towards the other, as shown in Fig. 58, thus forming a second cavity, *m*, the primative digestive cavity, which opens externally by a large, funnel-shaped orifice, the *gastrula mouth*, or *orifice* of invagination. As the direction cell does not persist in Arbacia, the relation between the principal axis and the ingrowth cannot here be made out, but the analogy of other animals gives great reason to believe that the invagination takes place along the principal axis, but at the nutritive pole or opposite the direction cell. The layer of cells is now divisible into two portions: the *endoderm* (*k*),

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which has been developed from the cells formed at the nutritive pole, and pushed inwards to form the lining wall of the digestive cavity, and the *ectoderm*, which is formed from the formative pole of the egg, and is to give rise to the outer wall of the body. The segmentation cavity (*i*), is no longer spherical, since the ingrowth of the digestive cavity encroaches upon it. The opacity of the egg of Arbacia prevents accurate study of its internal structure, but in Strongylocentrotus careful examination with high powers will show that the inner ends of the endoderm cells are separating off and forming stellate amœba-like cells, which are free in the segmentation cavity. These are the *mesoderm* cells, which after a time become arranged in a layer around the segmentation cavity on the inner ends of both ectoderm and endoderm cells. The outer surface of the body now becomes covered with fine cilia, and the embryo escapes from the egg-shell, and swims at the surface of the water.

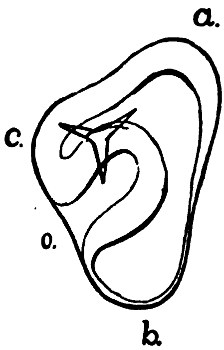

FIG. 59.

FIG. 59. — Side view of the larva shortly after its escape from the egg. (Drawn from nature by W. K. Brooks.)

During the second or third day, the embryo elongates in a line nearly at right angles to the principal axis, and at the same time becomes nearly triangular when seen in side view (Fig. 59). The angles are short and rounded, and one of them (*a*), is at what may now be called the anterior end of the body, another (*b*), at the posterior end, and a third near the middle of what will be called the ventral surface. The longest side (*a*, *b*), is nearly straight,

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and forms the dorsal surface, while the two short sides, *a*, *c*, and *c*, *b*, together make up the ventral surface.

The orifice of invagination (*o*), is now situated between the angle (*c*), and the posterior end, and the primative digestive cavity is no longer in the centre of the body, but bends towards the anterior end. Owing to the opacity of the embryo of Arbacia at this stage, the internal structure cannot be very clearly made out, but careful examination will show that the endoderm and the ectoderm of the anterior end of the body are still quite thick, while the ectoderm is quite thin at the posterior end. In the more transparent embryo of Strongylocentrotus at the same stage, the inner end of the digestive tract may be seen to be constricted off as a small sac, the *water pouch;* and the mesoderm cells may be made out as an internal layer of cells, lining the body cavity on the inner end of the digestive tract.

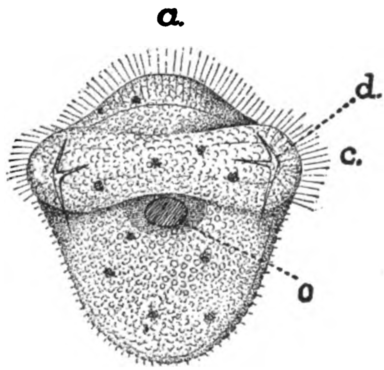

FIG. 60.

FIG. 60. — Ventral view of the same larva. (Drawn from nature by W. K. Brooks.)
a. Oral or anterior end. *b.* Posterior end. *c.* Ciliated ridge. *d.* Calcareous spicules. *e.* Orifice of invagination.

In a ventral view of the same larva of Arbacia at this stage (Fig. 60), the angle *c*, (Fig. 59) which is seen in a side view, is found to be the profile of an elevated ridge (Fig. 60, *c*), which runs across the ventral surface near the anterior end, and divides the body into a large posterior lobe (*b*), and a much smaller anterior lobe (*a*). The

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orifice of invagination, or anus (*o*), is situated just behind the centre of the ridge, and the cilia on the anterior lobe and ridge are long, while those on the posterior lobe and dorsal surface are small. A number of brownish-red pigment spots are scattered over the surface of the body.

At each end of the ridge, which will be spoken of hereafter as the ciliated ridge, there is a small, transparent, three-pronged *spicule* (*d*), the beginning of the calcareous skeleton of the larvæ. By comparing the side view with the ventral view, one of the prongs of this spicule will be seen to point towards the anterior lobe, one towards the posterior lobe, while the third runs along the ciliated ridge, towards the middle of the ventral surface.

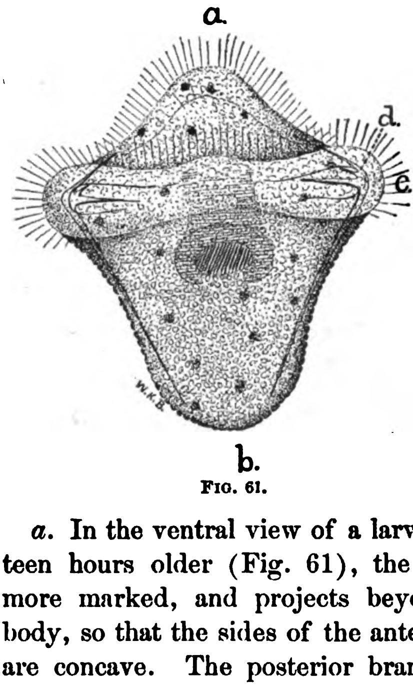

FIG. 61.

FIG. 61. — Ventral view of an older larva. (Drawn from nature by W. K. Brooks.)

IV. The Development of the Pluteus or swimming larva.

a. In the ventral view of a larva from twelve to eighteen hours older (Fig. 61), the ciliated ridge is much more marked, and projects beyond the outline of the body, so that the sides of the anterior and posterior lobes are concave. The posterior branch of the spicule, *a*, is greatly lengthened, and reaches nearly to the posterior end of the body, while a fourth branch has made its appearance, and runs towards the anterior edge of the ciliated ridge.

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In a side view (Fig. 62), the outline of the body is much as it was at the last stage, but the ectoderm is pushed inwards between the ciliated ridge (*c*), and the anterior lobe (*a*), so as to nearly meet the digestive tract, thus indicating the point (*m*), where the mouth is soon to be formed by the union of the ectoderm of the anterior end of the body to the endoderm of the inner end of the primative digestive cavity.

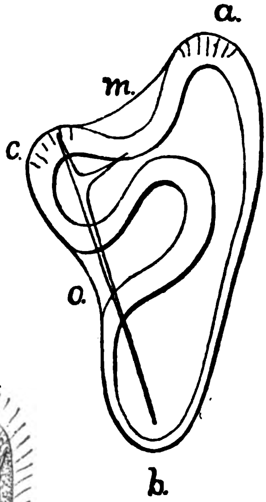

FIG. 62.

FIG. 62. — Side view of the same larva.

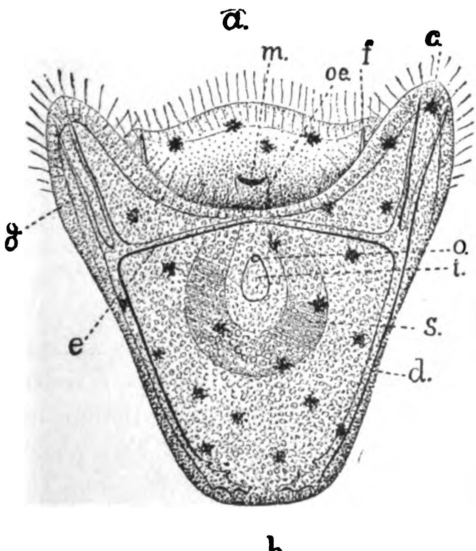

FIG. 63.

FIG. 63. — Ventral view of an older larva. (Drawn from nature by W. K. Brooks.)

a. Oral or anterior end. *b.* Posterior end. *c.* Post-oral arms. *d, e, f, g.* Spicular skeleton. *i.* Intestine. *m.* Mouth. *o.* Arms. *oe.* Œsophagus. *s.* Stomach.

b. At the end of the next thirty-six hours, the larva which is shown in ventral view in Fig. 63, and in side

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view in Fig. 64, has undergone very considerable changes, and is now sufficiently transparent to allow the internal organs to be more minutely examined.

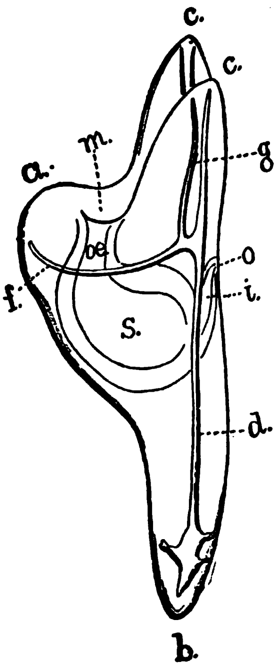

FIG. 64.

FIG. 64.—Side view of the same larva. (Drawn from nature by W. K. Brooks.)

The ends of the ciliated ridge have grown forward so as to form a pair of ear-like processes (Figs. 63 and 64, *c*, *c*), the rudiments of the pair of post-oral arms. The cells of the ridge have become thickened, columnar, and very different in appearance from the ordinary ectoderm cells. They carry long cilia, and are arranged in a row which runs out to the tips of the arms, and after bending around them, turns towards the dorsal surface, and bending forward, runs along the free edge of the oral lobe (*a*).

Great changes have also taken place in the spicular skeleton, which is now quite well developed. The rods (*d*), which run into the posterior lobe, and which we may call the lateral spicules, nearly meet each other upon the median line, and their free posterior ends have enlarged into irregular, club-shaped masses. The two branches which, at an earlier stage, ran towards the middle of the ciliated ridge, have met and united so as to form a solid bar (*c*), which may be called the ventral transverse rod, and which crosses the ventral surface. The branches which, at an earlier stage, ran towards the

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oral lobe, have lengthened so much that their tips (*f*), are visible in a ventral view. They are to become the spicules of the pre-oral arms. The fourth branch (*g*), is now double, and forms a fork, which runs nearly to the tip of each post-oral arm.

The digestive tract is now quite complicated. The mouth (*m*), which has been formed by the union of the integument to the wall of the digestive tract, is situated in the depression between the ciliated ridge and the oral lobe (*a*). It communicates through a short œsophagus (*o e*), with the large, flask-shaped, thick-walled stomach (*s*). The anus (*o*), is now very small, and it no longer opens directly into the stomach, but is joined to it by a smaller tube, the intestine (*i*), which is seen in a ventral view between the body wall and the stomach.

e. In from twenty-four to forty-eight hours more the larva will be found to have changed greatly, and it is now sufficiently transparent to allow the internal structure to be studied more easily. It is shown in Fig. 66, as it appears in a side view while swimming, and in Fig. 65 it is shown in a dorsal view. The specimen shown in this figure was a little flattened by the pressure of the cover glass which was used to confine it.

The post-oral arms (*c*, *c*), have grown so much that they now make about half the total length of the body, and the two spicules (*g*), which form the skeleton, have united to each other at intervals so as to form a ladder-like structure, with two long sides, and a number of cross-bars. The pigment spots are now very large and conspicuous, and there is a longitudinal row of them along each arm.

The outer angles of the oral lobe (*a*), are fashioned into a pair of ear-like processes (*a′ a′*), the rudiments of the

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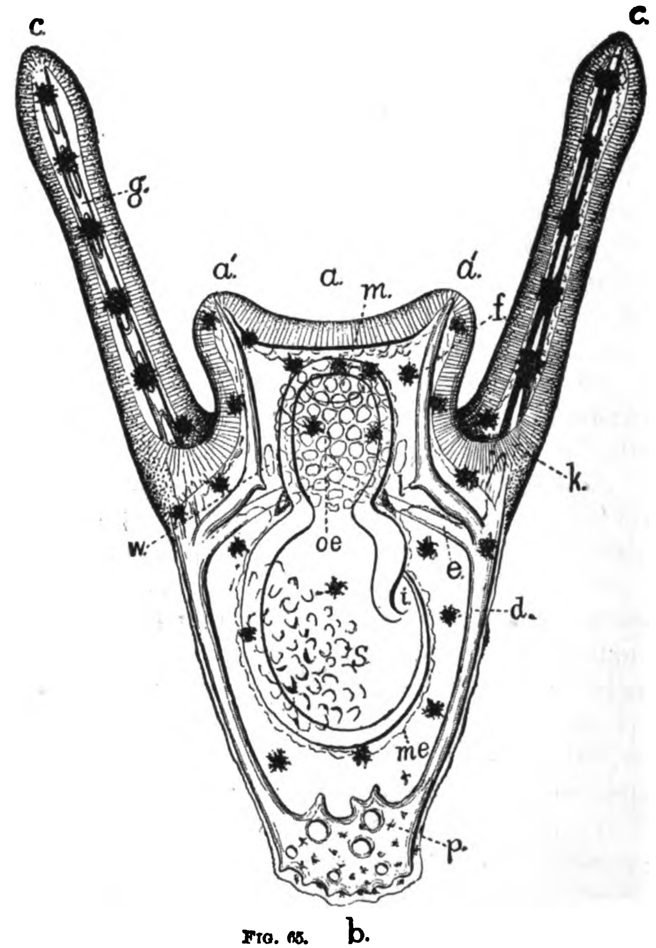

FIG. 65.

FIG. 65.—Dorsal view of a larva a little older, slightly flattened by pressure. (Drawn from nature by W. K. Brooks.)

a. Anterior end. *b.* Posterior end. *c, c.* Post-oral arms. *a' a'.* Pre-oral arms. *d.* Spicules of side of body. *e.* Ventral transverse spicule, seen through body. *f.* Spicule of pre-oral arm. *g.* Spicule of post-oral arm. *i.* Intestine, pushed to one side by pressure. *k.* Point where lateral arm is to be developed. *l.* Rudiment of a dorsal transverse spicule. *m.* Mouth. *m, e.* Mesoderm. *œ.* Œsophagus. *p.* Spicular skeleton at posterior end of body. *s.* Stomach. *w.* Water tubes.

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pre-oral arms, and the spicules which run into this lobe bend forward at *f*, or run into these arms to form their supporting framework.

At the point where the spicule (*f*), bends forward, it gives rise to a very small process (*l*), which points towards the middle of the dorsal surface, and is to become a transverse dorsal bar. In a dorsal view at this stage it is easy to see that the ciliated ridge which fringes the post-oral arms (*c*), bends back towards the dorsal surface at *k*, and runs forward along the edge of the oral lobe (*a*), and pre-oral tentacles (*a′ a′*). It therefore forms a closed circlet around the mouth. The posterior end (*b*), of the body is now quite transparent, and the ends of the two long, lateral spicules (*d*), have fused with each other, thus forming a large, irregular, perforated mass (*p*), which is covered with small pigment spots.

The different regions of the digestive tract are much more sharply distinguished than they were at earlier stages. The mouth (*m*), is a large, circular

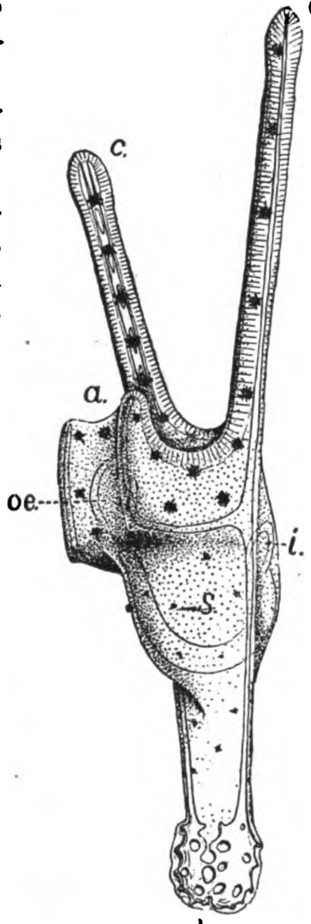

FIG. 66.

FIG. 66. — Side view of a larva at the same stage, while swimming. (Drawn from nature by W. K. Brooks.)
Letters as in Fig. 65.

opening, fringed with cilia, and it has moved from its primative position nearly to the anterior edge of the ventral surface of the oral lobe. In a dorsal view it is visible through the oral lobe.

The œsophagus (*oe*), is a long, thick-walled tube, lined with cilia, and communicating, through a constricted opening, with the large, globular, thick-walled stomach. The intestine (*i*), is an elongated, thick-walled tube on the ventral surface of the stomach, but the pressure to which the specimen shown in Fig. 65 was subjected has thrown it onto one side. At this stage the mesoderm (*me*), may be made out as a layer of irregular cells lining the body cavity, and covering the digestive tract.

On each side of the œsophagus, near the point where it joins the stomach, notice a pair of small, transparent bodies, the water-tubes (*w*). It is extremely difficult to follow the history of these important parts in Arbacia, but much easier to trace them in the transparent larvæ of Strongylocentrotus, where they may be seen at a much earlier stage.

d. A larva about twenty-four hours older is shown in dorsal view in Fig. 67. The shape of the body is about the same as in the preceding stage, but as Fig. 65 was drawn from a compressed specimen, while Fig. 67 was drawn from one which was swimming freely in the water, the figures show considerable difference of outline.

At this stage, notice especially the increased length of the pre-oral (*a′*, *a′*), and post-oral (*c*, *c*), arms; the formation of a little prominence (*n*), on each side in the angle between these arms; the increased length of the dorsal transverse spicules (*l*), which were only small spines at the last stage; the division of the œsophagus into two chambers; and the lengthening of the water-tubes (*w*). At this stage, the

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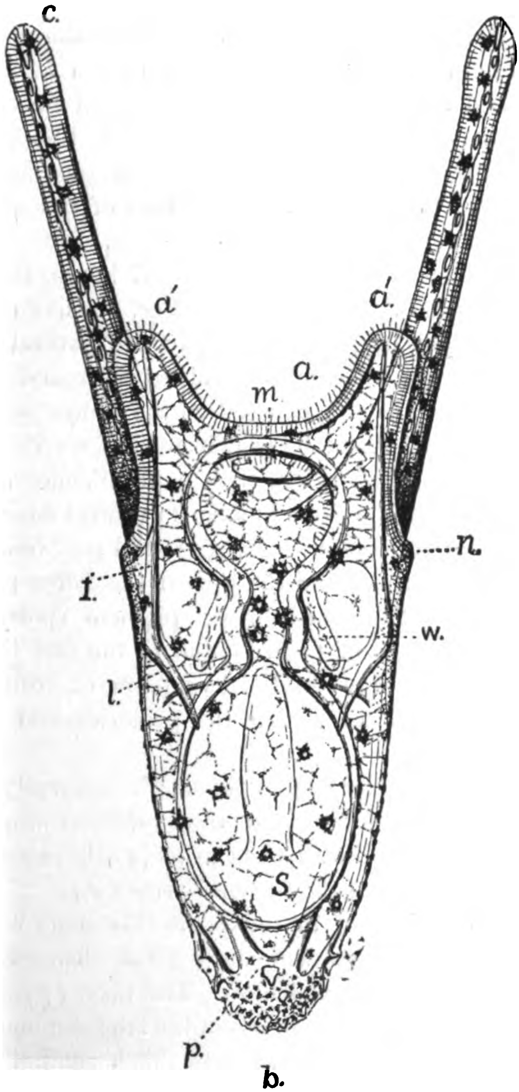

FIG. 67.

FIG. 67. — Dorsal view of a slightly older larva. (Drawn from nature by W. K. Brooks.)

a, *a'*, *b*, *c*, *f*, *l*, *m*, *p*, *s*, and *w*. As in Fig. 65. *n*. Rudiment of lateral arm.

posterior end of that water-tube which is on the right side in the figure may be seen to be united to the integument of the dorsal surface of the body. Careful examination will show that the body cavity is now filled with small, transparent, branched connective tissue corpuscles, which run across in all directions from the wall of the digestive tract to the inner surface of the body wall.

e. At the end of the next forty-eight hours, the larva which is shown in ventral view in Fig. 68, has changed its form, and the proportions of parts in several particulars, but the general structure is about the same.

The mouth (*m*), is now situated on the middle of the anterior edge of the oral lobe (*a*), instead of on its ventral surface, and a ciliated ridge, with a prominence (*a''*), at each end, has been developed along its ventral edge.

The two pairs of pre-oral arms (*a*), and post-oral arms, (*c*, *c*), are lengthened, and the tips of the latter pair are almost covered with reddish-brown pigment spots. The most marked change of form is due to the fact that the lateral angles (*n*), between the two pairs of arms, have travelled backwards nearly to the posterior end of the body.

The rudimentary arm (*n*), in this angle is scarcely larger than it was at the last stage, but the rudiments of a fourth pair of arms, the dorsal, lateral arms (*q*), have appeared between the angles and the pre-oral arms (*a'*).

Careful comparison of the larvæ at this stage with the figures of earlier stages will show great changes in the form and position of the spicules. The mass (*p*), formed by the fusion of the posterior ends of the lateral spicules (*d*), is undergoing resorbtion, and is now much smaller than it has been. The bar (*e*), which during the early stages ran across tne ventral surface close to the edge of the cil-

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iated ridge, and which at the stage shown in Fig. 65, lies at the point where the œsophagus joins the stomach, is

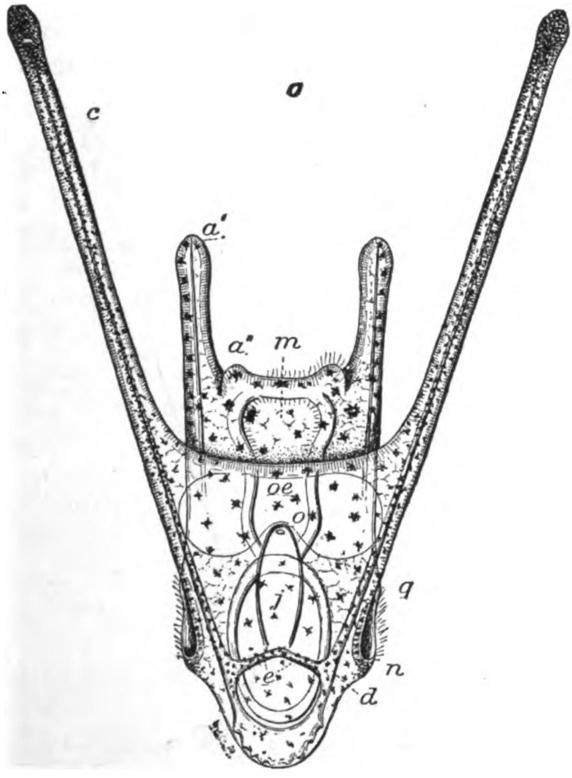

FIG. 68.

FIG. 68.—Ventral view of an older larva. (Drawn from nature by W. K. Brooks.)

a, *a'*, *b*, *c*, *d*, *e*, *f*, *g*, *i*, *m*, *oe*, *p*, and *s*. As in Fig. 65. *a''*. Lip. *n*. Point where ventral lateral arm is to be developed.

now pushed back so that it lies on the ventral surface of the posterior half of the stomach.

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It will be remembered that this bar was formed by the union of two processes which met and united in the median line. At this stage they separated again at this point on the slightest pressure, and a specimen may occasionally be found with quite a wide gap on the middle line.

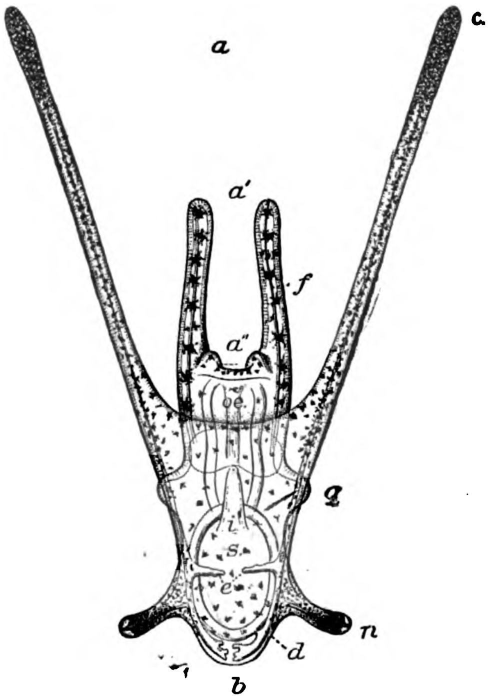

FIG. 69.

FIG. 69.—Ventral view of an older larva. (Drawn from nature by W. K. Brooks.)
Letters as in Fig. 68.

f. In from twenty-four to thirty-six hours more, the halves of the bar (Fig. 67, *e*), are widely separated, and are partially resorbed, and the posterior ends of the spic-

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ules (d) are also separated from each other, and nearly resorbed. The pre-oral and post-oral arms are somewhat longer than before, and more pigmented. The process (n) of Fig. 68, in the lateral angle of the ciliated ridge, is now a short, club-shaped arm (Fig. 69, n), thickly covered with small pigment spots, and containing a small, needle-

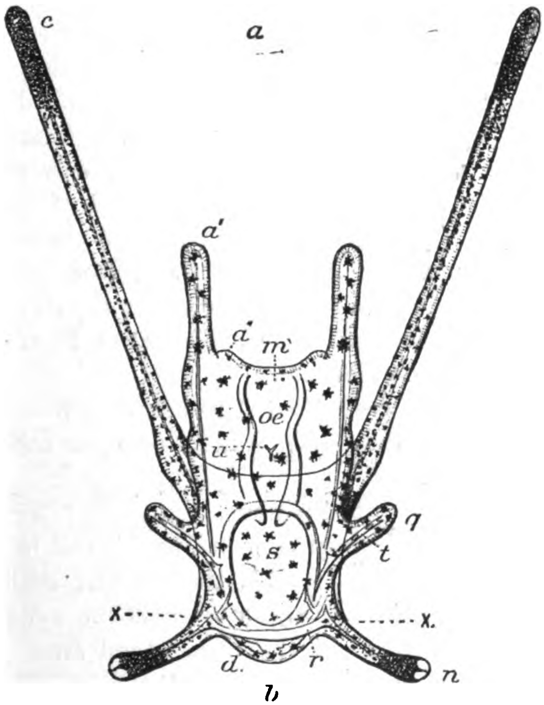

FIG. 70.

FIG. 70. — Dorsal view of an older larva. (Drawn from nature by W. K. Brooks.)

t. Spicule of dorsal lateral arms. Other letters as in Fig. 69.

like spicule. The process (q) is a little longer than before, but it is not yet a distinct arm, although traces of a small,

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ladder-like spicule may be detected in it by careful examination. The intestine is very much smaller than it was at the preceding stage, and it now joins the anterior edge, instead of the ventral surface of the globular stomach.

g. The larva forty-eight hours older is shown in dorsal view in Fig. 70. The arms (*n*) have lengthened slightly, and their spicules (*r*) have formed a bridge across the dorsal surface of the body, close to the posterior end. The posterior ends of the spicules (*d*) have almost disappeared. The arms (*q*) have lengthened, and an elongated, ladder-like spicule has appeared in each of them. The lateral angle between the pre-oral and post-oral arms, now occupied by the arm (*n*) is almost at the posterior end of the body. This change of position is due in part to the excessive growth of the organs anterior to the dotted line (*x*) in part to the absorption of organs posterior to this line, and in part to the movement of the angle (*n*) of Figs. 67 and 68 towards the posterior end.

Notice that a new spicule (*u*) makes its appearance on the middle line of the dorsal surface over the œsophagus at about this stage.

b. The fully developed pluteus.

This is shown in dorsal view in Fig. 71, and in ventral view in Fig. 72. In Fig. 73, the spicular skeleton is shown in its natural position, but without the soft parts.

Notice that the dorsal and ventral lateral arms (71 and 72, *q* and *n*) are now fully developed, and are supported by long spicules (*r* and *t*). The spicules (*r*) of the ventral, lateral arms are simple, and their inner ends meet on the median line to form a transverse bar (*v*) which carries at each end, where it joins the brachial portion, a short spine (*w*), which runs forwards and outwards.

The spicules (*t*) of the dorsal, lateral arms are ladder-

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like; and long, perforated spines (x) run from their proximal ends inwards and forwards over the dorsal surface of the stomach. A similar process (e) is sent inwards and forwards over the ventral surface of the stomach from the

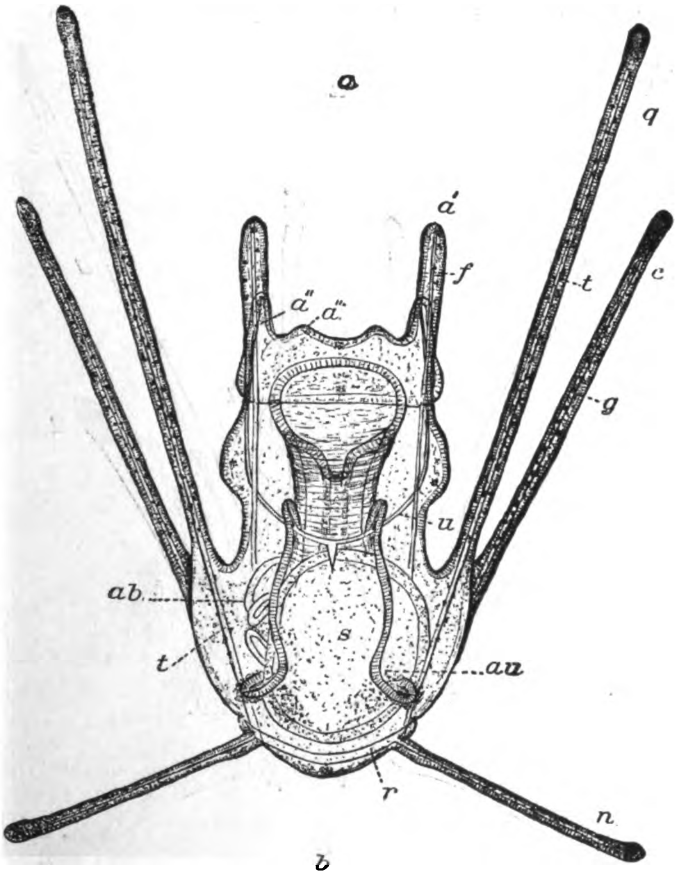

FIG. 71.

FIG. 71.—Dorsal view of the fully developed pluteus of Arbacia punctulata. (Drawn from nature by Mr. B. P. Colton.)

For explanation see Fig. 73.

spicule (*d*) of the post-oral arm (*c*). The spicules (*f*) of the pre-oral arms (*a'*) are now very long, and they reach nearly to the posterior end of the body.

A great fold or lip (Fig. 72, *o l*), now runs downwards from the anterior end of the body towards the ventral

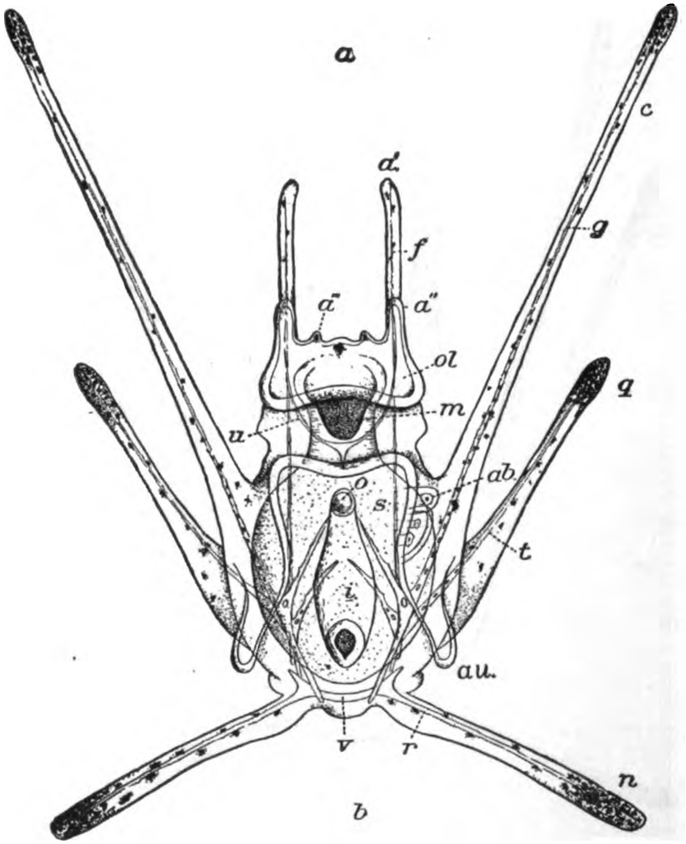

FIG. 72.

FIG. 72. — Ventral view of the fully developed pluteus of Arbacia. (Drawn from nature by Mr. H. Garman.)
For explanation see Fig. 73.

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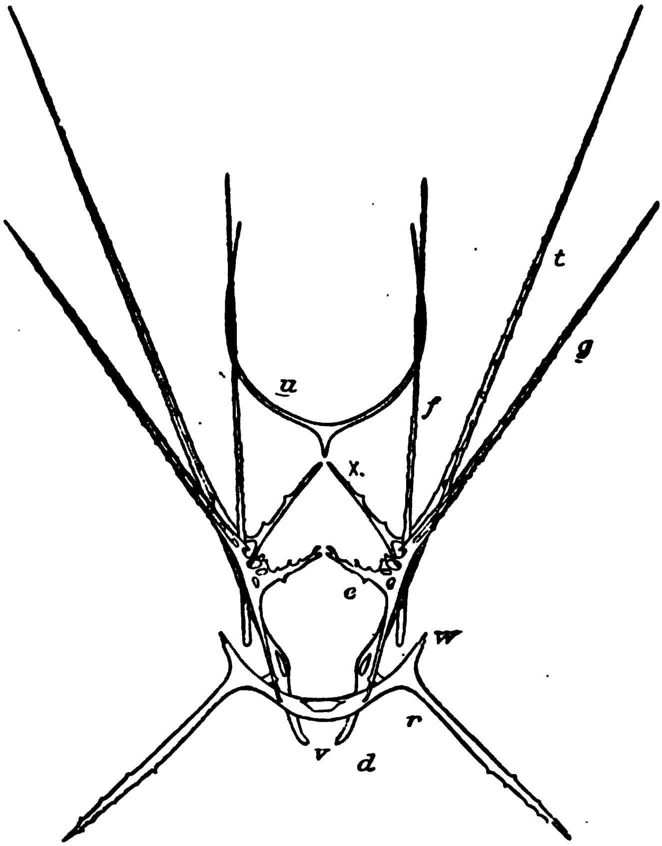

FIG. 73.

FIG. 73.—Ventral view of the spicular skeleton of the fully developed pluteus of Arbacia punctulata. (Drawn from nature by Mr. H. Garman.)

Letters of reference for Figs. 71, 72, and 73.

a Anterior end of body. *a'*. Pre-oral arms. *a''*, *a'''* Secondary oral arms. *a b*. Ambulacral feet of young sea-urchin. *b*. Posterior end of body. *c*. Post-oral arms. *d*. Lateral spicules of body. *e*. Transverse ventral spicules. *f*. Spicules of pre-oral arms. *g*. Spicules of post-oral arms. *i*. Stomach. *m*. Mouth. *n*. Ventral lateral arms. *o*. Anus. *o l*. Oral lobe. *q*. Dorsal lateral arms. *r*. Spicules of ventral lateral arms. *s*. Stomach. *t*. Spicules of dorsal lateral arms. *u*. Median dorsal spicule. *v*. Posterior transverse bar. *w*. Spine from spicule *r*. *x*. Spine from spicule *t*.

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surface, and hangs over the mouth. The anterior edge of this lip is prolonged into two pairs of secondary oral arms (a'' and a'''), those nearest the middle line being much the smallest.

The median dorsal spicule (u) which appeared at the last stage, has now lengthened, to form a large *U*, which lies on the dorsal surface, and sends a branch into each of the outer secondary oral lobes.

On the ventral surface of the body (Fig. 72), the ciliated ridge has grown backwards on each side, between the post-oral lobe and the bases of the post-oral arms, to form a pair of ear-like processes ($a\,u'$), which are fringed with cilia.

On the dorsal surface (Fig. 71) a similar pair of ear-like processes ($a\,u$) have been formed by the development and folding of two lines of ciliated cells, one on each side of, and parallel to the middle line of the body.

At this stage, the stomach is slightly pushed to one side by the development of five hollow tubes (Figs. 71 and 72, $a\,b$), on one side of it. These are the first five tubular ambulacra of the young sea-urchin, and they are on the right side of the stomach in a dorsal, on the left in a ventral view.

In the star-fish larva, where their origin can be more satisfactorily studied, it will be seen that they are developed from the left water-tube, and not from the actual walls of the stomach.

i. The development of the young sea-urchin.

As the development of the young echinoderm within the larva can be studied to more advantage in the star-fish than in the sea-urchin, its formation will be more fully described under that heading, but the following points should be noticed in the pluteus of Arbacia.

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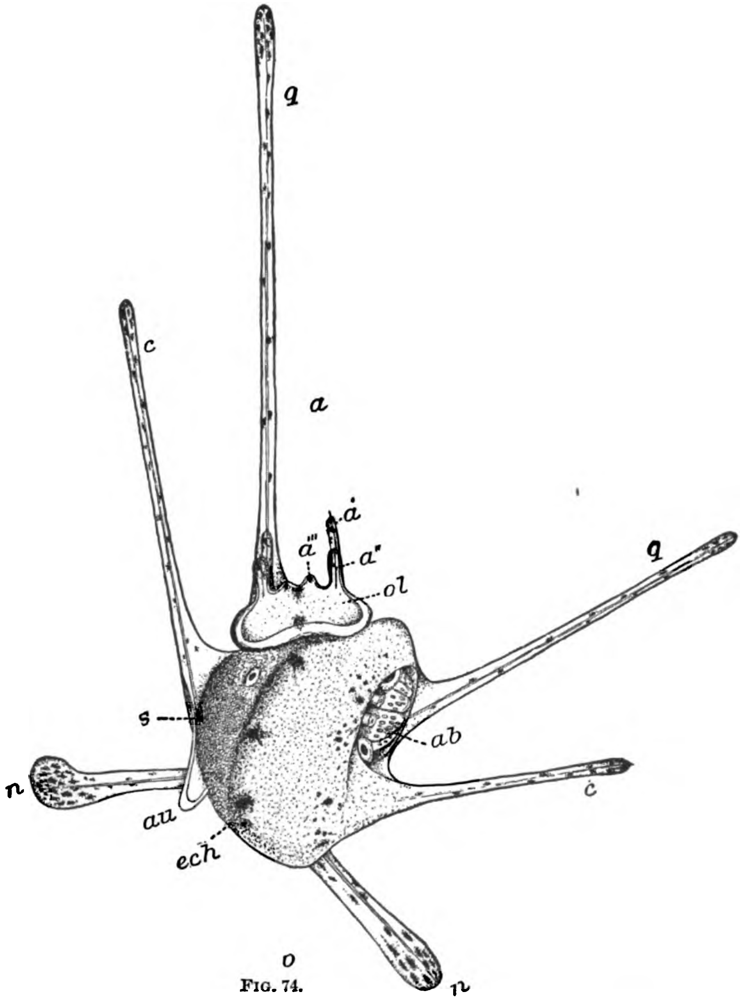

FIG. 74.

FIG. 74. — Pluteus, with young sea-urchin, seen from the ventral surface. (Drawn from nature by Mr. H. Garman.)

a. Anterior end of body. *a'*. Pre-oral arms. *a''*, *a'''*. Secondary oral arms. *a b*. Ambulacral feet of sea-urchin. *a u*. Ventral auricular process. *b*. Posterior end of body. *c*. Post-oral arms. *c*, *e*, *b*. Ab-oral surface of sea-urchin. *n*. Ventral lateral arms. *o l*. Oral lobe. *q*. Dorsal lateral arms. *s*. Stomach.

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The larva soon becomes asymmetrical, as shown in ventral view in Fig. 74, and the pre-oral arms (*a'*) begin to disappear, while the dorsal, lateral arms (*q*) become longer than any of the others.

A large circular opening makes its appearance on the right side of the body (ventral view), between the bases of the post-oral arm (*c*) and the dorsal, lateral arm (*q*) and through this opening the ambulacral feet (*a b*) of the sea-urchin may now be protruded. They are five in number, one for each ray of the sea-urchin, and around them there is a circle of fifteen flattened, perforated plates, the first set of spines of the young sea-urchin.

The stomach (*s*) is now pushed over on to the left side of the body, and a granular belt (*e c h*) with pigment spots, around its right side, indicates the position of the developing body-wall of the ab-oral surface of the sea-urchin. The pluteus now becomes still more distorted, and in about twenty-four hours it assumes the form shown in Fig. 75, which is a dorsal view. The mouth and pre-oral arms (*a'*, *a''*) of the pluteus are pushed to the left, and the growing sea-urchin now fills nearly the whole body. The two ventral, lateral arms (*n*, *n*) are nearly parallel to each other, and the post-oral arms (*c*) and dorsal, lateral arms (*q*) are thrown back towards the posterior end of the body. The five ambulacral feet are now protruded from the surface of the body, and a disc of small, calcareous plates appears in the sucker with which each of them ends. Between their bases are the fifteen spines, (*s*), arranged in five sets, of three each.

For some time the larva is able to bend back the arms as shown in the figure, and, protruding its feet, to crawl as an echinoderm; or, pulling back the feet, and pushing the arms into their original position, to swim as a pluteus.

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The mouth of the echinoderm is now formed as a new opening, which penetrates to the stomach of the pluteus from the right side of the body, in the centre of the circle of ambulacral feet.

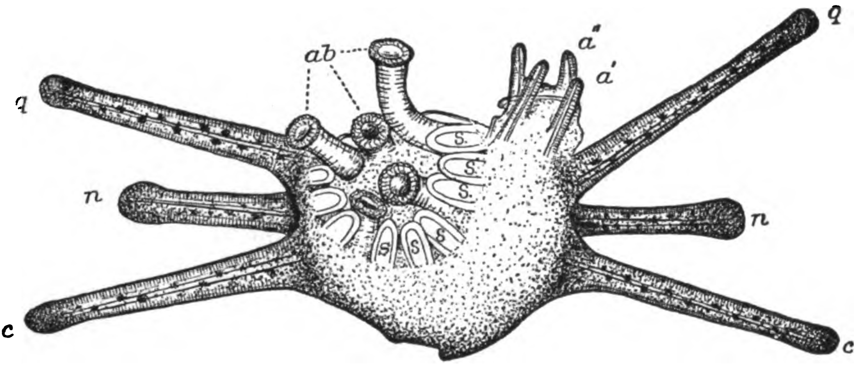

FIG. 75.

FIG. 75. — The same, a little older, from the dorsal surface. (Drawn from nature by Mr. B. P. Colton.)
Letters as in Fig. 74.

The sea-urchin grows and protrudes more and more from the opening, and the arms of the pluteus are finally bent upwards so as to project from the ab-oral surface of the body, as shown in Fig. 76. The integument of the larva still covers the sea-urchin as a delicate, transparent, outer skin, and the oral lobe can still be recognized for a short time. The manner in which the arms finally disappear is somewhat peculiar. The wall of the arm flows, like a retracted pseudopodium, down onto the surface of the body, leaving the bare spicule projecting from the ab-oral surface. The spicules soon drop off, the dentary apparatus is developed, and the young sea-urchin assumes the form shown, from the oral side, in Fig. 77.

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VI. The swimming larva of the starfish.

The larvæ of starfish, which are known as Bipinnaria and Brachiolaria, are constructed on essentially the same plan as the pluteus of the sea-urchin, although there are great

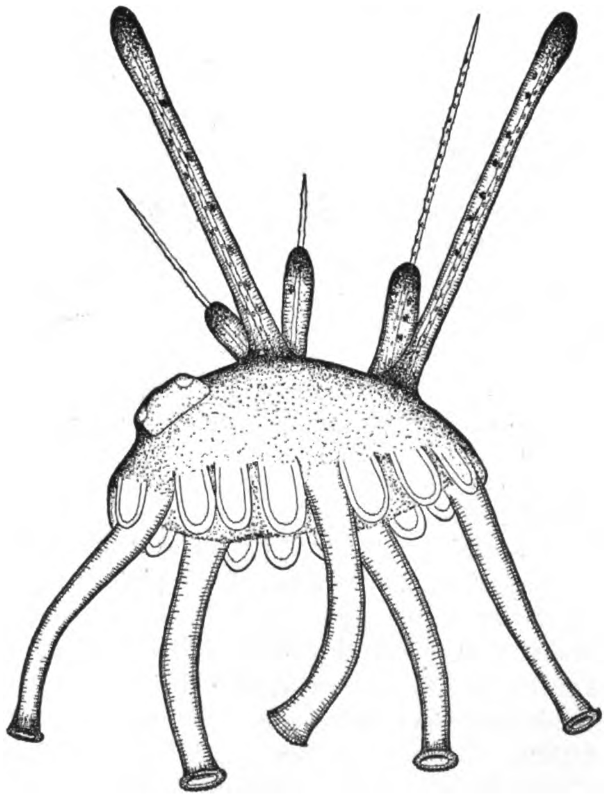

FIG. 76.

FIG. 76. — The sea-urchin, with the arms of the pluteus disappearing. (Drawn from nature by Mr. B. P. Colton.)

differences in details of structure. They may usually be obtained at the surface of the ocean in early summer with

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the tow-net or dip-net, and since their greater size renders them much more fit than the pluteus for studying the mode in which the young echinoderm is formed inside the larva, the student should if possible rear some of them in small aquaria, and study the development of the young starfish. The full-grown larva is about one-twelfth of an

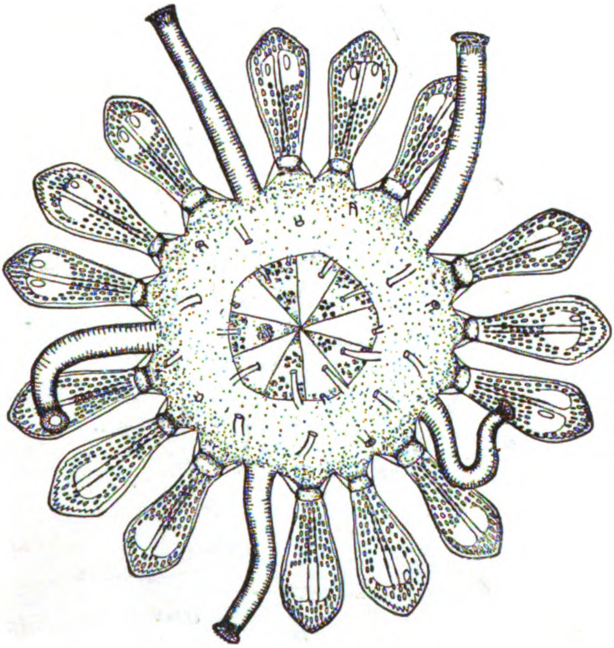

FIG. 77.

FIG. 77. Oral surface of the young sea-urchin. (Drawn from nature by Mr. H. Garman.)

inch long, transparent, and of the shape shown in Fig. 78. This figure shows the bipinnarian larva of a southern starfish, but the brachiolaria· of our common species is almost exactly like it, and the student should have no difficulty in recognizing it when captured.

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a. The structure of the larva.

At first sight there seems to be little likeness between the starfish larva (Figs. 78 and 79), and the pluteus of a sea-urchin, but more careful examination shows that

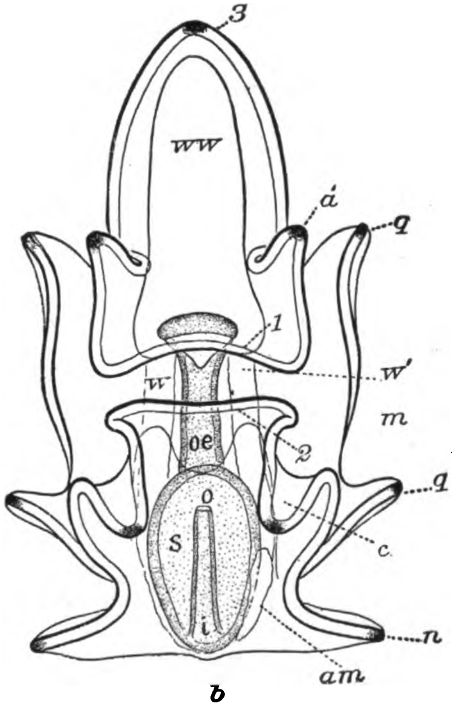

FIG. 78.

FIG. 78.—Bipinnarian larva of starfish, as seen in ventral view. (Drawn from nature by E. B. Wilson.)

a. Anterior end. *a'.* Pre-oral arms. *b.* Posterior end. *1.* Pre-oral ciliated ridge. *2.* Post-oral ciliated ridge. *3.* Anterior median ventral lobe. *4.* Anterior median dorsal lobe. *c.* Post-oral arms. *i.* Intestine. *m.* Mouth. *n.* Lateral arm. *o.* Anus. *oe.* Œsophagus. *q, q.'* Dorsal lateral arms. *s.* Stomach. *ww'.* Water tubes. *am.* Flattened posterior end of left water tube.

they are much alike. The mouth of the pluteus is at the anterior end of the body, while the anterior end of the body of the starfish larva is elongated into a long lobe (Fig. 78, *a*), and the mouth (*m*) is about midway between

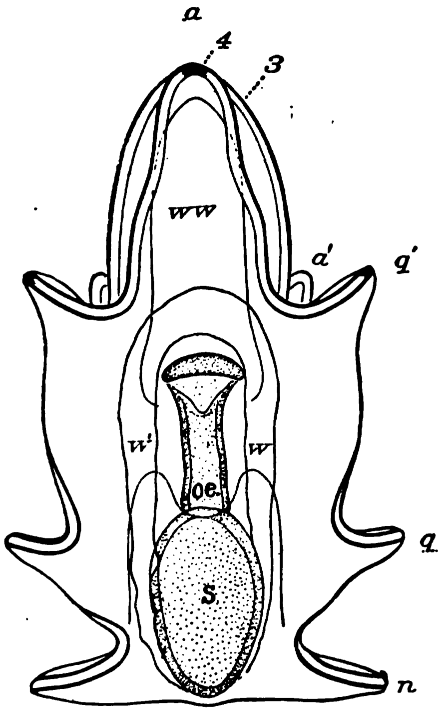

FIG 79.

FIG. 79.—Dorsal view of the same larva. (Drawn from nature by E. B. Wilson.)

Letters as in Fig. 78.

the anterior end (*a*), and the posterior (*b*) on the ventral surface. It lies, as it does in the sea-urchin pluteus, in a furrow, with a ciliated ridge (*1*) in front of it, and another (*2*) between it and the anus (*o*). The long œsopha-

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gus (*oe*), the globular stomach (*s*), and the ventral intestine (*i*), are very similar to those of the pluteus.

The ciliated ridges (*1* and *2*) before and behind the mouth, are prolonged into a number of paired lateral arms, but these are shorter and more numerous than those of the pluteus, and they have no supporting skeleton.

In the pluteus the ciliated ridge which passes in front of the mouth, fringes the pre-oral arms, and then, running back onto the lateral arms, fringes the post-oral arms, and then passes across the ventral surface behind the mouth, so that its course forms a single closed circlet.

In the bipinnaria the pre-oral ciliated ridge (*1*), after fringing the pre-oral arms (*a'*), runs forward on each side to form a lobe (Fig. 78, *3*) on the ventral surface of the large oral lobe (*a*). It thus forms a small closed circlet on the ventral surface in front of the mouth, and encloses a surface which is entirely ventral, and which is known as the pre-oral plastron.

The ciliated ridge (*2*), which passes between the mouth and the anus, becomes bent into a pair of arms (*c*), which answer to the post-oral arms of the pluteus. It then runs backwards on each side to form a pair of lateral arms (*n*), and then runs forward along the edges of the dorsal surface (Fig. 79), folding out to form two pairs of lateral dorsal arms (*q* and *q'*). The two sides finally meet at the tip of the dorsal surface of the anterior lobe (*a*), where they form an unpaired lobe (Fig. 79, *4*). This circlet surrounds an area partly ventral and partly dorsal, and known as the anal plastron. There are thus two closed circlets of cilia in the starfish larva, instead of one as in the sea-urchin, and one of these is in front of the mouth and on the ventral surface, while the other runs between the mouth and the anus, and fringes the dorsal surface.

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The larva shown in the figures is known as a Bipinnaria. A *Brachiolaria* is a larva of the same type, but with a system of fleshy, unciliated arms, known as brachiolar arms, at the anterior end of the body, between the loops *3* and *4*.

b. The water-system of echinoderm larvæ.

Before the mouth (Fig. 62, *m*) joins the stomach (*o*), two little pouches, the water-tubes, or peritonæal vesicles, are constricted off from the stomach, at the point where the œsophagus is to unite with it. After the œsophagus joins the stomach one of these lies on each side of it as in Fig. 65, *w*). They then lengthen as shown in Fig. 67, *w*, and the tip of the one which is on the left in a ventral view unites to the integument of the dorsal surface of the body, and forms an external opening there.

The two water-tubes now lengthen, as shown at *w w′* in Figs. 78 and 79, and run backwards onto the sides of the stomach, where they form a pair of flattened pouches. They also run forward, and bending towards each other in front of the mouth, unite to form a single large pouch (Figs. 78 and 79, *ww′*).

c. The formation of the echinoderm in the body of the larva.

The flattened portion of that water-tube which lies on the left of the stomach (Fig. 78, *am*), now becomes folded out to form five lobes (Fig. 80, *am*); Fig. 81, am^1, am^2, am^3, am^4, am^5), which are to become the water-tubes of the five rays of the starfish. These five lobes are arranged in a rosette, with the one which is to belong to the anterior ray of the starfish (am^3) pointing towards the posterior end, and those which are to belong to the two rays of the bivium (am^1, am^5), slightly separated from each other.

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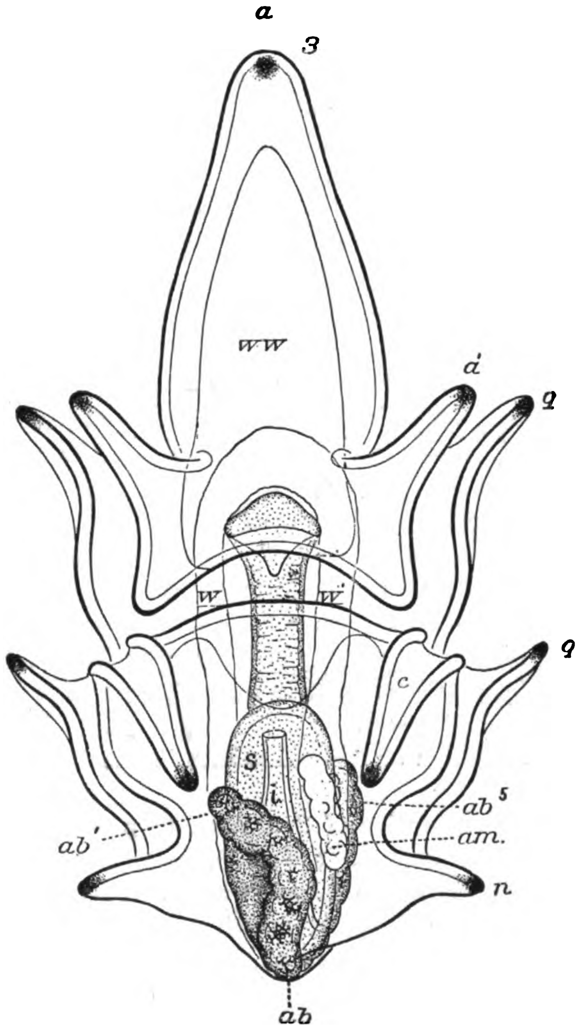

FIG. 80.

FIG. 80. — Ventral view of an older larva. (Drawn from nature by E. B. Wilson.)

am. Ambulacral area of developing starfish. *ab*. Ab-oral area of developing starfish. ab^1, ab^5. Its free ends.

Other letters as in Fig. 78.

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On the outer surface of the corresponding portion of the opposite, or right water-tube, and therefore on the opposite side of the stomach, calcareous spicules make their appearance, and build up a spiral band (*ab*), which

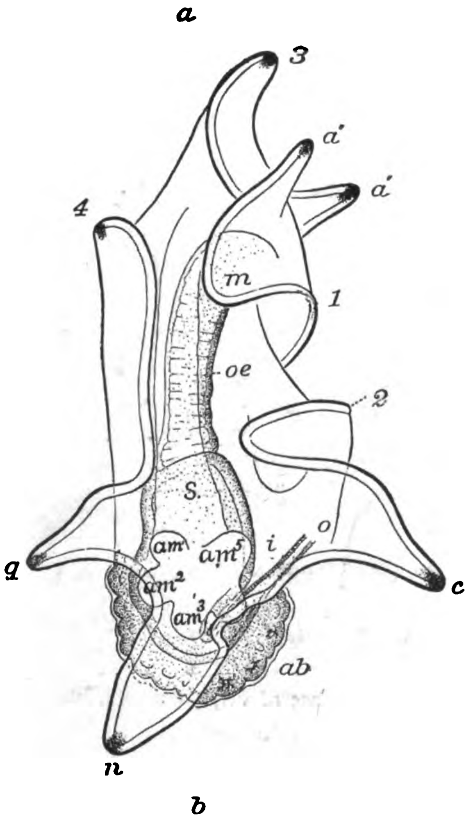

FIG. 81.

FIG. 81. — Side view of the same larva. (Drawn from nature by E. B. Wilson.)

*am*1, *am*2, *am*3, *am*4, *am*5. The five water tubes of starfish.

Other letters as in Fig. 80.

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is to form the integument of the upper surface of the body of the starfish. The extremities of this band (*ab*[1] and *ab*[5], Fig. 80) are widely separated, and it is divided into five lobes, corresponding to the five rays, each lobe being again divided into four smaller lobes.

The upper and lower surfaces of the future echinoderm are thus seen to be on the right and left sides respectively of the stomach of the larva. They include between them part of the right water-tube, which is to become the body

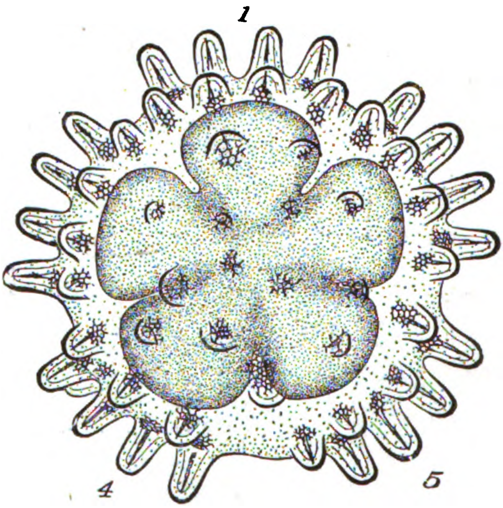

FIG. 82.

FIG. 82. — Ab-oral surface of very young starfish. (Drawn from nature by E. B. Wilson.)

cavity of the starfish; part of the stomach, which is to become the digestive tract of the starfish; and part of the left water-tube, which is to become the water-system.

d. The young starfish.

These portions grow and fold towards each other; a new mouth is formed in the centre of the rosette on the left

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side of the larva; the body of the larva is absorbed or cast off, and the young starfish escapes, in the form shown from above in Fig. 82. In this figure *1* is the anterior ray, and *4* and *5* the two rays which were at the ends of the spiral band in the larva. The calcareous skeleton develops rapidly, and the sucking feet grow out from the water-tubes, as shown from below in Fig. 83. Notice that

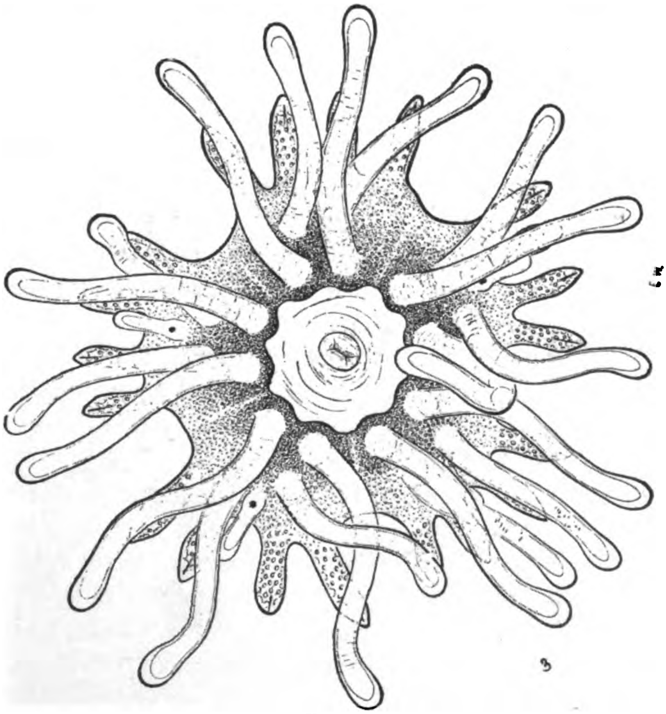

FIG. 83.

FIG. 83. — Oral surface of the same starfish, a few days older. (Drawn from nature by E. B. Wilson.)

the radiating water-tubes are, at this stage, internal, and covered by the skeleton, as in the adult sea-urchin, and that there are no ambulacral furrows.

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XV.—THE GENERAL ANATOMY OF THE EARTH-WORM.

(*Lumbricus.*)

I. External Form.

The external characteristics may be studied in an alcoholic specimen, or one which has recently been killed with ether. If alcoholic specimens are used, they should be placed in water for a few hours. The various reproductive apertures are much more conspicuous in some specimens than in others, according to the sexual condition of the animal, and if there is difficulty in finding them in one specimen, another may be tried. Their positions vary somewhat, according to the species, and the numbers given here apply to L. terrestris, but any other species will answer for examination.

In the examination of the external form, notice:

1. The long, cylindrical body, divided by contrictions into rings, or *segments*, of which there may be as many as three hundred and fifty.

2. The *anterior end*, or that at which the segments are largest.

3. The brownish-red, slightly iridescent, dorsal surface.

4. In the median dorsal line, the bright-red, *dorsal bloodvessel* may be seen through the integument, and in a small, transparent, living animal, irregular pulsations of this vessel can be detected.

5. The *ventral surface* is of a much lighter color, and more iridescent than the dorsal.

6. At a point about one-third the length of the body from the anterior end, notice a thick, glandular white ring or saddle, the *girdle*, or *clitellus*, which is formed by the

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thickening of the dorsal and lateral portions of about seven segments from the twenty-ninth backwards. The ventral portions of these segments are much less specialized than the upper portions.

7. The delicate, chitinous, transparent *cuticle* which loosely invests the external surface of the animal, and which may be slipped off from a specimen which has lain for a few hours in water.

8. The *locomotor spines*, or *setae*. In the earthworm, these are so small that a lens is needed to detect them, but if a worm be pulled backward gently between the fingers, the resistance offered by the setae can be felt. They are arranged in four longitudinal double rows, two rows on each side, along the ventral surfaces of all the segments except the first, second, third, fourth, and last.

The outer pair are on the line where the dark-colored dorsal region shades off into the lighter-colored ventral, and the inner pair are a little nearer the ventral median line.

9. The *mouth* is at the anterior end ot the body, and leads into a large, eversible, buccal pouch. If a living earthworm be held gently between the fingers, near the anterior end of the body, the animal can be made to evert this pouch.

10. The *anus*, a small aperture at the posterior end of the last segment.

11. The *segments* and *apertures* of the body.

a. The first segment is not a complete ring, and forms a proboscis, or upper lip.

b. The remaining segments are complete rings, and are alike as far as the ninth.

c. The ventral portions of the ninth, tenth, and eleventh segments are thickened so as to form white glandular

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prominences, which are used as organs of adhesion during the act of copulation. The two pairs of inner setae of each of these segments are situated near the outer ends of these prominences, and are larger than those of the adjacent segments.

d. On the sides of the body, in a line with the outer setae, and between the ninth and tenth, and tenth and eleventh segments, are the external apertures of the four *seminal receptacles.*

e. On the fourteenth segment, just exterior to the setae of the inner row, are the openings of the *oviducts.* These are very small, but, in a large specimen, they may be seen with a lens after the cuticle has been removed.

f. On the fifteenth segment, just outside the inner setae, are two somewhat prominent papillae, each of which has a slit-like aperture, the orifice of the *vas deferens*, or male reproductive aperture.

g. Segments twenty-nine to thirty-six have already been noticed as the girdle. Posterior to the thirty-sixth, the segments suddenly decrease in width, and are then repeated, with little modification, to the posterior end.

h. On the median dorsal line there is a row of pores, one on the anterior margin of each segment, by which the body-cavity opens externally.

II. General Anatomy.

A large specimen should be selected for dissection, and killed by placing it for a few minutes in a bottle or tumbler with a few drops of ether. With a sharp knife or a pair of fine-pointed scissors make an incision along the median dorsal line, and pin out the integument of the anterior third of the body, under water.

1. The *perivisceral fluid.*

The body cavity will be found to contain, especially in

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the posterior segments, a milky fluid, the *perivisceral fluid*. Place a drop of the fluid on a glass slide, gently cover it, and examine it under a microscope. It consists of a coagulable, albuminous plasma, which contains great numbers of transparent, granular, amœboid corpuscles. In addition to these normal constituents, it usually contains foreign bodies, such as Gregarinæ, parasitic Infusoria, and Nematoid worms, broken setae, etc.

2. The *muscular dissepiments*, or diaphragms, which extend inwards from the integument to the wall of the digestive tract, and imperfectly separate the body cavities of adjacent segments.

3. The *digestive tract*, a nearly straight tube, without convolutions, extending along the median line of the body from the anterior to the posterior end.

4. Upon its dorsal surface, and closely united to its wall, observe the red *dorsal* or *supra-intestinal blood-vessel*.

5. The digestive tract is divided into several well-marked regions: —

a. *The pharynx*, a large, broad, muscular organ (Fig. 84, *n*), extending from the second to the seventh segment, and similar, in shape and connections, to the sucking chamber of the leech.

(i.) The radiating muscular fibres which bind it to the integument.

(ii.) The *cephalic* or *supra-œsophageal ganglia;* two pear-shaped bodies (Fig. 84, *a*), upon the dorsal surface of the pharynx, in the third segment of the body, and united to each other by their broad ends upon the dorsal median line.

From their smaller outer ends arise two fibres, which pass down around the pharynx to unite with the ventral nerve chain.

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b. The *œsophagus;* a long, nearly straight, thin-walled, elastic tube, much smaller than the pharynx, and extending from the eighth to the sixteenth segment (Fig. 84, *c*, *d*). It is slightly constricted at the points where it passes through the partitions between the segments, and its muscular fibres are continuous with those of the partitions.

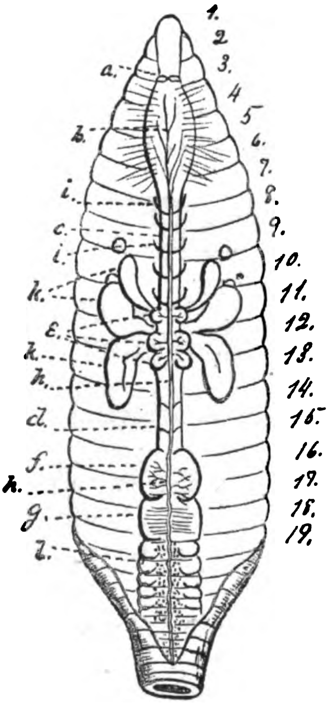

FIG. 84.

(i.) In the tenth, eleventh, and twelfth rings, the white testes (Fig. 84, *k*), surmount and overlap the œsophagus.

(ii.) If these are carefully displaced, three pairs of highly vascular pouches (Fig. 84, *e*), the *œsophageal glands*, will be seen between them, projecting from the sides of the œsophagus.

FIG. 84. — The anterior end of the earthworm, opened along the dorsal surface, to show the digestive organs. (From Lankester, *Anatomy of the Earthworm*. Quar. Jour. Mic. Sc., 1864, P. VII., Fig. 5.)

1, 2–19. The nineteen anterior segments. *a*. Cerebral ganglia. *b*. Pharynx. *c*. Œsophagus. *d*. Posterior portion of it. *e*. Œsophageal glands. *f*. Crop. *g*. Gizzard. *h*. Dorsal blood-vessel. *i*. Aortic arches. *k*. Testes. *l*. Intestine.

The first pair are a little larger than the others, and if they are removed from the œsophagus, and opened upon a slide, and examined with a microscope, they will be found to contain solid crystalline bodies, which dissolve, with active effervescence, when treated with acid.

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c. At about the sixteenth segment, the digestive tract suddenly dilates, and forms a large, muscular, highly vascular, heart-shaped crop (Fig. 84, *f*), which, in the living animal, usually exhibits muscular contractions, even when the animal has been opened.

d. Immediately succeeding the crop is the "*gizzard*" (Fig. 84, *g*), a firm-walled, cylindrical, highly vascular chamber.

e. This is followed by the *intestine* (Fig. 84, *l*), which passes to the posterior end of the body with very little modification. Its walls are greatly folded and sacculated, especially in the anterior portion.

f. A layer of brownish-green, delicate, easily-ruptured glands, the *hepatic glands*, which cover the dorsal surface of the intestine, and surrounding the dorsal blood-vessel, extend as far forward as the œsophagus.

6. The *dorsal blood-vessel.* This extends along the dorsal surface of the digestive tract, in contact with its walls, as a distinct vessel (Fig. 84, *h*), from the posterior end of the body to the anterior end of the œsophagus, where it breaks up into a number of smaller vessels, which ramify upon the pharynx and œsophagus.

In the living animal, the main trunk may be seen to dilate and contract at intervals, but no part of it is modified to form a special pulsating organ. It gives rise, at intervals, to large lateral trunks, which pass outward and downward around the digestive tract to join the infra-intestinal vessel. These arches are very large and prominent in the eighth to the thirteenth segments, and are here furnished with small, saccular, pulsatile dilations.

The dorsal vessel also gives rise to smaller lateral vessels, which pass to the muscular partitions, and to the integument and digestive organs.

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a. Cut the dorsal vessel, and place a drop of the red fluid on a slide; note that it coagulates quickly. Cover another drop, and examine with a microscope. It is a clear, red fluid, which contains small, flattened, oval or fusiform colorless corpuscles, much smaller, and with sharper, more regular outlines than those from the body cavity.

The digestive tract may now be cut off posterior to the pharynx, and removed from the body, in order to expose the organs which lie below. Great care is necessary to avoid injuring the testes while removing that part of the œsophagus which lies between them.

If a fresh specimen has been used, it should now be covered with strong alcohol, in order to coagulate and harden the delicate transparent portions of the body.

7. The *nervous system*. This is made up of: —

a. The *cerebral ganglia*, which, as has been pointed out, are situated upon the dorsal surface of the pharynx in the third segment (Fig. 84, *a*; Fig. 84, *h*).

(i.) A large nerve may be traced forward from each half of the cerebrum (Fig. 87, *i*). These nerves soon divide into smaller branches, which pass to the anterior segments, especially the first.

(ii.) From the outer ends of the cerebrum two commissures (Fig. 87, *d*,) pass outward and downward around the œsophagus to unite with the ventral chain.

(iii.) Four or five nerves may be seen to run backward from the upper portion of each half of this collar (Fig. 87, *g*). They soon penetrate the muscular walls of the pharynx, and their terminations cannot be made out without further dissection.

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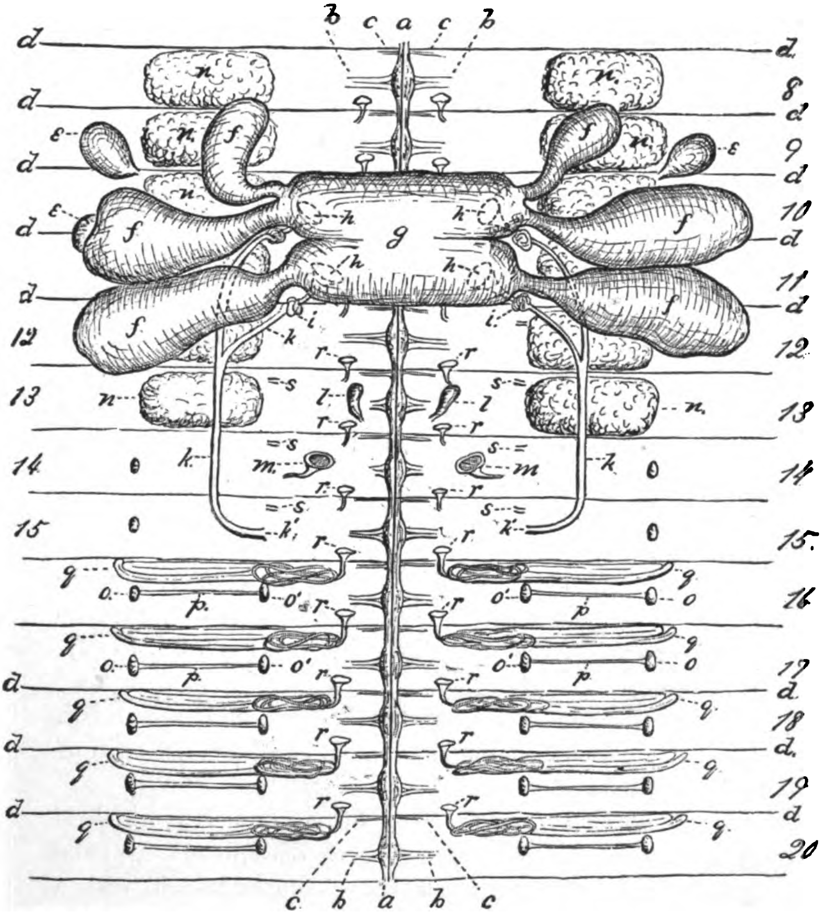

FIG. 85.

FIG. 85. — Diagram of the ventral surface of the body cavity of the eighth to twentieth segments of the earthworm. (Drawn by W. K. Brooks.)

8, *9*, *10–26*. Body cavities of the segments. *a*. Nervous system. *b*. Nerves from ganglia. *c*. Nerves from commissures. *d*. Diaphragms between the segments. *e*. Receptacula seminis. *f*. Testes. *g*. Vesicula seminis. *h*. The opening of the vasa deferentia, represented as seen

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through the vesicula seminis. *i.* Convoluted portion of vas deferens. *k.* Vas deferens. *k'.* Its external opening in the fifteenth segment. *l.* Ovaries in the thirteenth segment. *m.* Oviducts in the fourteenth segment. *n.* Enlarged setigerous glands in the eighth to thirteenth segments. *o.* Ordinary external setigerous gland. *o'.* Ordinary internal setigerous gland. *p.* Fibre connecting *o* and *o'*. *q.* Segmental organ. *r.* Its internal orifice. *s.* Its external orifice, shown in the thirteenth, fourteenth and fifteenth segments, from which the other parts of the glands have been removed.

b. The *ventral nerve chain.* This is made up of: —

(i.) Two commissural cords, which run side by side, and in contact, from the fourth to the last segment (Fig. 85, *a*; Fig. 87, *a*).

(ii.) A double or bilateral ganglionic enlargement (Fig. 87; *5*, *6*, *7*), in each segment posterior to the third.

(iii.) Two pairs of nerves (Figs. 85 and 87, *b*), originate in each ganglion, and pass to the muscles and viscera of each segment.

(iv.) A pair of nerves originate in the commissure anterior to the ganglion in each segment, and supply the posterior face of the muscular partition (Figs. 85, 87, *i*).

8. The *segmental organs.*

In each segment except the first, second, and third, there is a pair of segmental organs (Fig. 85, *q*), each of which consists of

a. A *ciliated funnel* (Figs. 85, *r*, and 87), which is attached to the anterior face of each dissepiment near the median line. It is a small, funnel-shaped pouch, with a wide, ciliated opening, which communicates with the body cavity. A much smaller tubular neck passes through the partition, and thus connects the funnel with

b. The glandular portion of the organ; a long, greatly-convoluted, delicate-walled tube (Fig. 86, *a*, *b*, *c*, *d*), lined with cilia, and richly supplied with blood-vessels, and

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connected by a mesenteric membrane with the posterior face of the partition.

c. The *external opening* (Figs. 85, *s*, and 87), on the ventral surface of the segment which contains the glandular portion of the organ. It is a very small aperture just outside the inner bunch of setae.

9. The *reproductive organs.*

These, in their order of succession, are—

1. The *seminal receptacles ;* 2. The *testes;* 3. The *seminal vesicle;* 4. The *vasa deferentia ;* 5. The *ovaries ;* 6. The *oviducts.*

a. The *testes.* Three pairs of large, white, slightly vascular glands (Fig. 85, *f*), which project above and overlap the œsophagus in the ninth, tenth, and eleventh segments. The two anterior pouches unite with each other, while the third is undivided.

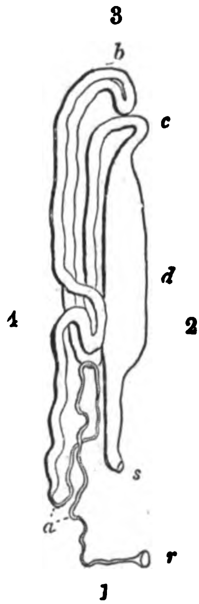

FIG. 86.

FIG. 86. — Segmental organ of earthworm, magnified twenty-five diameters, and freed from the surrounding tissues.

1. Central end. *2.* Anterior margin. *3.* Peripheral end. *4.* Posterior margin. *r.* Opening into body cavity—"ciliated funnel." *s.* External opening. *a.* Convoluted portion. *b.* Outer fold. *c.* Inner fold. *d.* Muscular sac.

(i.) Cut off a piece from one of the testes, and place a drop of the white fluid which it contains under the microscope. In it will be found mother cells and spermatic filaments in all stages of development.

b. The lower end of each testis is sharply constricted, and united by a short neck to the *seminal vesicle*, a large,

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white, membraneous pouch (Fig. 85, *g*), which extends across the median ventral floor of the tenth and eleventh segments, and receives the testes of both sides of the body.

c. On the lower surface of this organ, near the median line, are the four ciliated, funnel-shaped openings of the vasa deferentia (Fig. 85, *h*), one on each side in the tenth, and one on each side in the eleventh segment. They are bound by connective tissue to the lower surface of the seminal vesicle, but have no communication with its cavity. The male fluid escapes from the receptacle by the rupture of its walls, and is then drawn by the cilia into these funnels.

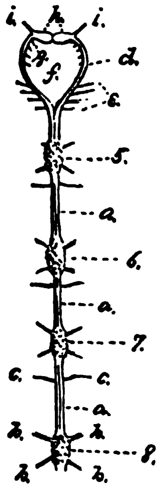

FIG. 87.

FIG. 87.—Anterior portion of nervous system of earthworm. (From Lankester, *Anatomy of the Earthworm*, Quar. Jour. Mic. Sc., N. S., vol. V. P. vi., Fig. 6.) Magnified about five diameters.

a. Commissural fibres. *b*, *b*, *b*, *b*. The two pairs of nerves which arise from each ganglion. *c*, *c*. The nerves which pass from the commissure to the diaphragm. *5*, *6*, *7*, *8*. The ganglia of the fifth, sixth, seventh, and eighth segments, respectively. *d*. Œsophageal collar. *e*. Nerves from collar to the muscles of fourth segment. *f*. Space occupied by pharynx. *g*. Nerves to pharynx. *h*. Cerebral ganglia. *i*. Nerves to first segment.

d. The *vasa deferentia* may be traced as delicate, white tubes running backward from the funnels (Fig. 85, *k*). The four tubes are at first separate, but in the thirteenth segment the pair on each side unite, and thus form two ducts, which run backward between the inner ends of the two rows of setae of each side, and open externally in the fifteenth segment.

e. The *seminal receptacles;* four nearly spherical, vas-

cular, white sacs, situated just outside the testes, between the ninth and tenth and the tenth and eleventh segments (Fig. 85, *e*).

(i.) Remove one of them, and examine its contents with the microscope: It will be found to be filled with a compact mass of fully-developed spermatic filaments.

g. The detection of the ovaries and oviducts is a matter of some difficulty. In a large specimen, which has been pinned out under alcohol, on the ventral surface of the thirteenth segment, close to the nerve cord, are a pair of small, white, pear-shaped organs, about one-sixteenth of an inch long, the *ovaries* (Fig. 85, *l*).

They are attached by their stalks to the ventral body wall, and a microscopic examination shows that they are membraneous sacs, without ducts, and filled with ova, in all stages of development. The ripe ova escape, by the rupture of the walls, into the body cavity, and are then taken up by the mouths of the oviducts.

h. The oviducts are a pair of small, trumpet-shaped, ciliated tubes, which open externally by their small ends, near the inner setae of the fourteenth segment (Fig. 85, *m*). The inner, enlarged end of each oviduct bends forward, passes through the partition between the thirteenth and fourteenth segments, and opens in the cavity of the thirteenth segment by a large, funnel-shaped, ciliated mouth, which is close to the ovary of the same side.

10. The *integument*. After the viscera have been removed, the longitudinal muscles of the body wall may be examined.

They consist of—

a. A large ventral band.

b. Two lateral bands.

c. A dorsal band.

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11. The *setigerous glands.* Four of these may be seen in each segment, projecting into the body cavity, between the ventral and lateral, and lateral and dorsal muscular bands (Fig. 85, *o*, *o'*). In the ninth, tenth, eleventh, and sometimes in the eighth, twelfth, and thirteenth segments, the glands of the inner setae are much enlarged, and form conspicuous white pouches (Fig. 85, *n*).

In the segments posterior to the thirteenth, a muscular band, (*p*), will be seen running from the gland of the outer to that of the inner setae.

XVI.—THE MICROSCOPIC STRUCTURE OF THE EARTHWORM.

SPECIMENS for microscopic work should be hardened in alcohol, by placing them in eighty per cent alcohol for about twelve hours, and then transferring them to strong or absolute alcohol.

Cut one of the specimens into sections about half an inch long; stain them in a very dilute solution of picro-carmine for two or three hours, and then return them to the strong alcohol to extract the water. Mount them in paraffine, and cut a number of thin sections from each, as described in Section V. Examining the sections with a power of one hundred to two hundred diameters, notice: —

I. The *body wall;* which is made up of five concentric layers.

a. The *cuticle*, or outer layer, is a delicate, transparent, structureless layer (Figs. 88, *a*, and 89), which is perforated by fine canals or pores perpendicular to the surface. It is loosely attached to the surface of the body, and is very easily detached from a fresh specimen.

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b. Examine the outer surface of a piece of cuticle which has been stripped off from the body of a fresh specimen, and notice the fine parallel lines which cause the iri-

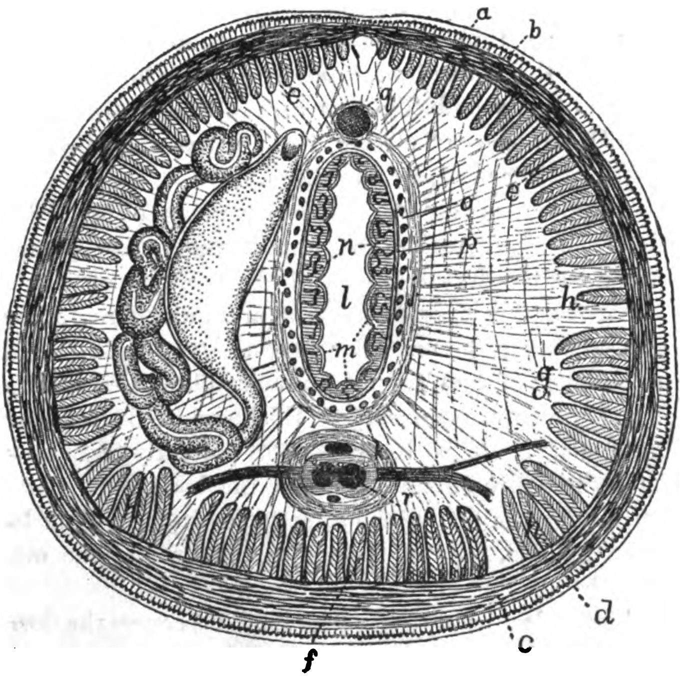

Fig. 88.

Fig. 88. — Transverse section through the œsophageal region of the body of Lumbricus terrestris, in the plane of a dissepiment. (Copied with slight changes from Claparède. *Histologische Untersuchungen über den Regenwurm*. Zeit. f. Wiss. Zool., xix. Taf. xliv. Fig. 1.)

a. Cuticle. *b*. Hypodermis. *c*. Circular layer of muscles. *d*. Layer of longitudinal muscles. *e*. Dorsal band. *f*. Ventral band. *g*. Lateral bands. *h*. Bands between setae. *j*. Circular muscular fibres around œsophagus. *k*. Circular muscular fibres around nervous system. *l*. Cavity of œsophagus. *m*. Cuticle of œsophagus. *n*. Epithelial layer of œsophagus. *o*. Layer of circular muscles around œsophagus. *p*. Layer of longitudinal muscles. *q*. Dorsal vessel. *r*. Ventral nerve cord.

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descence of the living animal. If the cuticle is found difficult to remove, it may be loosened by placing the animal in warm water for a short time.

c. The hypodermis (Figs. 88, *b*, and 89), or cellular layer by which the cuticle is excreted. When examined with a high power a thin section of a favorable specimen will show that the stained protoplasm of this layer forms a polygonal honeycomb-like structure of thin vertical plates, and that the spaces between these plates are filled by a transparent inter-cellular substance.

d. A layer of circular muscular fibres (Figs. 88, *c*, and 89) lies just within the hypodermis. The pigment which gives the dorsal surface of the body its dark color is situated in this layer, in the form of minute dark granules scattered among the muscular fibres.

e. A layer of longitudinal muscular fibres (Figs. 88, *d*, and 89), which varies greatly in thickness in different parts of the body. This layer is not perfectly continuous around the entire circumference of the body, but is interrupted along the line of the setae, so as to form eight longitudinal bands, four of them very narrow and the other four wider.

1. The widest band (Figs. 88, *e*, and 89) covers the dorsal surface and sides, and may be called the dorsal band. It extends from the uppermost setae on one side to the corresponding setae on the other side.

2. The ventral band (Figs. 88, *f*, and 89) is much narrower, and covers the ventral surface, between the lowest setae.

3. A lateral band (Figs. 88, *g*, and 89) runs on each side between the two pairs of setae.

4. There are two narrow bands (Figs. 88, *h*, and 89) on each side, between the two setae of each pair.

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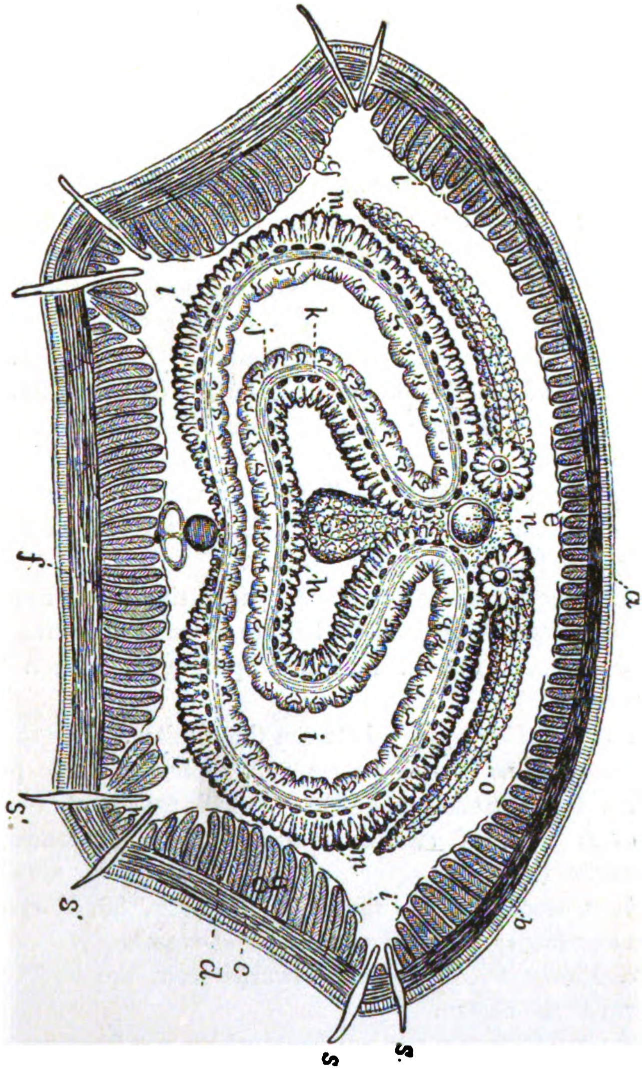

FIG. 89.

FIG. 89. — Transverse section through the body of Lumbricus terrestris near the middle of the intestine. (Slightly changed from Claparède. Taf. xliv., Fig. 2.)

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FIG. 89. — *a* to *h*. As in Fig. 88. *i*. Cavity of intestine. *j*. Epithelium of intestine. *k*. Layer of circular muscular fibres around intestine. *l*. Layer of longitudinal muscular fibres around intestine. *m*. Green layer on outer surface of intestine. *n*. Dorsal vessel. *o*. "Liver."

f. Notice that the muscular fibres of this layer do not form a thin stratum on the inner surface of the layer of circular fibres, but are arranged in bundles or leaflets, which project into the body cavity so as to form a series of parallel ridges. Each ridge consists of a central plate, with muscular fibres on each side of it; and, in transverse section, has somewhat the appearance of a feather. A longitudinal section of the body-wall will show that the circular muscles have a similar feather-like structure when cut across.

g. The body cavity is lined by a vascular layer (Fig. 89, *c*) which covers the inner surface of the muscular bundles, and is rich in small vessels.

h. Covering these vessels and separating them from the body cavity, the nuclei of a delicate layer of epithelial cells may be made out in favorable specimens, with a high power.

II. The *dissepiments* between the somites. In a section which contains the whole or a part of one of these partitions, notice the muscular fibres, which consist of: —

a. A layer of circular fibres (Fig. 88, *j*) around the digestive tract.

b. A second set of circular fibres (Fig. 88, *k*) around the nervous system and ventral blood-vessel.

c. Fibres which radiate inwards from the body wall towards the centre.

d. A few nearly vertical fibres which run from the dorsal to the ventral surface.

e. The surface of the partition is covered by an epithelium, which is rather difficult to detect.

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III. The *Setae.* In a section which contains setae, notice: —

a. The complicated system of muscles running from the inner end of the seta to the surrounding integument.

b. Small, partially developed setae near the inner end of each large one.

c. The sheath around the outer end of the seta, formed by a tubular infolding of the cuticle.

IV. The *Nervous System.*

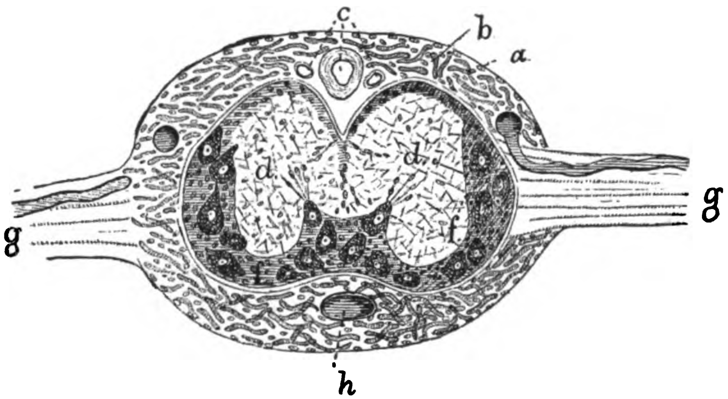

FIG. 90.

FIG. 90. — Transverse section through the ventral ganglia, near the middle of the body. (From Claparède. Taf. xlvii., Fig. 4.)

a. Surface epithelium. *b.* Muscular layer. *c.* "Tubular fibres." *d.* The two ganglia. *f.* Outer layer with large ganglion cells. *g.* Lateral nerves. *h.* Ventral blood-vessel.

Examine with a high power, — two hundred and fifty to five hundred diameters, — a section which passes through one of the ganglionic enlargements of the ventral nerve cord, and notice: —

a. The layer of epithelium (Fig. 90, *a*) which forms its outer sheath.

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b. A thick layer of longitudinal muscular fibres (Fig. 90, *b*) between which numbers of small, nucleated cells are scattered.

c. The *tubular bands;* three longitudinal bands (Fig. 90, *c*) which lie in the muscular layer, on the dorsal side of the nerve cord.

d. The two ganglia (Fig. 89, *d*) which are imperfectly separated from each other along the median line. Each consists of: —

1. A layer of large, granular, nucleated ganglion cells (Fig. 89, *f*) which lie upon its ventral surface and sides.

2. A central and dorsal non-transparent area (*d*) which consists almost entirely of extremely fine intertwined nerve fibres.

e. The nerves (Fig. 90, *g*) which run off on each side, and consist of fine fibres like those in the dorsal portion of the ganglion.

g. The blood-vessels; especially the large ventral vessel (*h*) which runs along the body below the nervous system.

V. The *Digestive Organs*.

a. In a section which passes through the pharynx, notice: —

1. The central cavity (*l*) which is reduced to a narrow slit by the folding together of its walls. The form of this slit varies greatly in sections from different parts of the pharynx.

2. A delicate layer of transparent cuticle, which lines the cavity.

3. The epithelium, formed by a single layer of large nucleated cells.

4. The very numerous blood-vessels, which lie just outside the layer of epithelium.

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5. The greater part of the wall of the pharynx is made up of a mass of muscular fibres, which are entwined in all directions.

b. In a section through the œsophagus (Fig. 88), notice that, —

1. The muscular wall is divided into an outer layer (*o*) of longitudinal fibres, and an inner layer (*p*) of circular fibres.

2. The epithelium (*n*) is thrown into folds or papillæ, and each contains a looped branch of a blood-vessel.

3. The cuticle (*m*) is more distinct than in the sections of the pharynx.

c. In a section through the œsophageal glands notice that these are simple pouches formed by pushing out the wall of the œsophagus into the body cavity. The most anterior pair contain the calcareous bodies noticed in Section XV.

d. Sections through the crop and gizzard are much like those through the œsophagus, except that the muscular layer is much more developed.

e. In sections through the intestine (Fig. 89) notice the very peculiar manner in which the dorsal wall (*h*) is pushed down towards the ventral, thus reducing the cavity (*i*) to a narrow slit. Notice that the epithelium (*j*), the vascular layer, the layer of circular muscular fibres (*k*), and the layer of longitudinal muscular fibres (*l*) are arranged as in the œsophagus.

1. Outside the layer of longitudinal fibres notice a thick layer (*m*) of granular greenish cells, which is reflected above onto the dorsal vessel (*q*) and its branches, thus forming the so-called liver (*o*).

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XVII.—THE GENERAL ANATOMY OF THE LEECH.

Macrobdilla decora.

I. SPECIMENS for examination should be killed with chloroform, and they may then be examined, or they may be preserved in alcohol. If the large pond leech cannot be procured, the medicinal leech may be used. Examining a fresh or an alcoholic specimen, notice the following external characteristics.

a. The arched, *dorsal surface* of the long, ribbon-like body. This surface is distinguished by its dark, olive-green color, as well as by the regular arrangement of the pigment spots.

b. The flattened, light-colored *ventral surface*, upon which the pigment spots are very irregularly distributed.

c. The *anterior end* of the body may be recognized by its protrusible proboscis, or sucker, which is formed by the upper lip, and projects over the mouth.

d. The posterior end of the body terminates in a much larger sucker, with an unbroken circular outline. The disk of the posterior sucker is imperforated, and faces ventrally.

e. On the dorsal surface, note:

1. The *annuli* or rings which encircle the body. These are about one hundred in number, and must not be mistaken for the true somites into which the body is divided.

2. The *proboscis* is made up of four incomplete annuli, and the first complete ring.

3. The ten black *eyes*, which are arranged in a horseshoe upon the dorsal surface of the anterior end of the body.

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Two of these eyes are upon the first annulus.
Two upon the second.
Two upon the third.
Two upon the fifth.
Two upon the eighth.

It is probable that each pair of eyes corresponds to a body somite. The first annulus must therefore be regarded as the first somite; the second annulus as the second somite; the third and fourth annuli as the third somite; and the fifth, sixth, and seventh annuli as the fourth somite.

4. The two rows of black pigment spots along the edges of the body.

5. A median dorsal row of light-colored spots. Each somite posterior to the fourth is made up of four or five annuli, and the pigment spots are on the first annulus of each somite. The body is thus seen to be made up of twenty-five somites, without counting the posterior sucker, which is shown, by its mode of development, to consist of seven somites.

6. On the dorsal surface in the groove which separates the most posterior annulus from the sucker, notice the anus.

7. Make a drawing of the dorsal surface, to show these points.

f. On the ventral surface, notice:—

1. The *mouth*, bounded anteriorly and ventrally by the proboscis, and ventrally by the ventral portion of the fourth annulus.

2. A thickening of the median ventral portion of the thirtieth annulus, in the centre of which the *male reproductive organ* is placed. In specimens which have been killed with chloroform, the penis usually projects a little from the opening.

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3. The *female reproductive orifice* is on the median line, between the thirty-third and thirty-fourth annuli.

4. A nearly square region, formed by the thickening of the ventral portions of the thirty-ninth, fortieth, and forty-first annuli, and pierced by two pairs of fine pores, the external openings of the *mucous glands*.

5. The external apertures of the *segmental organs*, With a hand-lens two small papillæ may be seen projecting backwards from the posterior margin of every fifth annulus; one on each side, near the edges of the ventral surface. The openings are upon the posterior annulus of each somite, that is, the annulus just in front of the one which has a pigment spot upon its dorsal surface.

6. Make a drawing of the ventral surface, to show all these points.

II. Internal Structure.

Specimens for dissection may be killed with chloroform, and preserved in seventy-five per cent alcohol. A day or two before they are to be dissected, they should be placed in water, to soften them.

Cut through the integument, along the middle of the dorsal surface, from the second or third annulus to the last but one. With a pair of fine forceps lift up one edge of the integument, near the middle of the body, and with a pair of fine-pointed scissors cut the blood-vessels, muscles, and connective tissue which bind it to the upper surface of the digestive tract. Pin the flap of skin down on to a flat piece of cork or a wax tablet, under water, and then free the opposite edge, and pin it out in the same way. Work forwards and backwards from these two pins, pinning down the integument at short intervals. If this is carefully done, the whole digestive tract will now be exposed in place.

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a. The digestive tract consists of a *buccal pouch*, a *pharynx*, a *stomach*, and an *intestine*. The buccal pouch may be examined later. In the other parts, notice: —

1. The muscular, thick-walled, tubular pharynx, which forms about the first tenth of the total length of the digestive tract. It is bound, by radiating muscular fibres, to the body wall.

It is much larger in the middle than at the ends, where the wall contains circular muscles, which may by their contraction entirely close the tube.

3. The "stomach" is a large sacculated pouch, which joins the pharynx abruptly, and nearly fills the body cavity. Its walls are much thinner than those of the pharynx, and are only very slightly muscular. It occupies about five-sixths of the total length of the body, and is divided, by deep constrictions which run nearly to the middle line, into eleven pouches or chambers, each of which, except the last, fills the body cavity of one somite, while the constrictions which separate the pouches correspond to the partitions between the somites. These partitions may be seen to run into the spaces between the pouches, so as to form imperfect dissepiments between the cavities of adjacent somites.

The cavity of the stomach is made up: —

(i.) Of a central tube, which is continuous with the pharynx along the middle of the body, and is greatly constricted at each dissepiment.

(ii.) Of the cavities of the sacculi upon each side of this central tube.

The squeezing to which the blood is subjected in this "stomach," in order to separate the fluid from the solid portions, is effected by the pressure of the outer wall of the body, only slightly aided by the muscles of the stomach itself.

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(iii.) The posterior end of the "stomach" forms a small papilla which projects into the "intestine."

4. The "intestine" enlarges a little, near its anterior end, and then tapers gradually to the anus.

5. Make a sketch of the digestive tract, showing these points.

b. Cut through the middle of the dorsal wall of the digestive tract, with a pair of scissors, in order to expose the interior. Wash out, with a stream of water, any food which may remain in the stomach; and, examining the various regions with a lens, notice: —

1. The pharynx. Its walls are very thick and muscular, and are joined to the integument by radiating muscles, which, by distending its cavity, produce a sucking action.

2. The cavity is largest in the middle, and opens into the stomach through a small round aperture surrounded by muscles.

3. Six or eight large longitudinal bundles of muscles give to the inner wall of the pharynx a plicated appearance. By the action of these muscles the blood which has been sucked into the pharynx by the contraction of the radiating muscles, is driven backward into the sacculi of the stomach.

4. Each sacculus is divided, on each side the middle line, into an anterior and a posterior chamber. The posterior chamber is the larger, and is prolonged downwards and backwards.

5. The posterior chambers of the last or eleventh sacculus are much larger than the others, and run backwards to form two large horn-like diverticula, which reach nearly to the posterior end of the body.

6. Between the anterior ends of these diverticula the

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"intestine" originates, and runs backwards on the median line of the body. It is much smaller than the "stomach," tubular and muscular.

7. Near its posterior end the intestine dilates to form an ovoidal *colon*.

8. From this a very small and short rectum runs to the dorsal anus, which lies between the last annulus and the sucker.

c. Cut the digestive tract at the anus, and at about the middle of the pharynx, and carefully dissect it away and remove it, to expose the organs which lie below. On the inner surface of the ventral body-wall, notice: —

1. The median ventral nerve-cord, made up of: –

(i.) A series of ganglia; one in each of the somites except those at the anterior end of the body. These ganglia give rise to lateral nerves which may be traced out into the body-wall.

(ii.) The commissures which join these ganglia into a chain.

2. The ventral blood-vessel, a transparent tube which surrounds the nervous system, and sends off lateral branches.

3. The two lateral blood-vessels, running along the sides of the body.

4. The segmental organs; a row of eighteen pairs of convoluted tubular organs, one for each somite of the body, situated just inside the lateral vessels. Each of these is connected with a transparent membraneous globular vesicle.

5. The male reproductive organs.

(i.) About one-sixth of the length of the body from the anterior end the globular muscular penis will be seen. It is prolonged into a siphon-shaped tube, which opens exter-

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nally upon the median line, a little behind the globular portion.

(ii.) Two convoluted white glandular bodies, the vesicula seminales, are situated a little anterior to, but in the same somite with, the penis. They open into this at one end, and at the other they connect with —

(iii.) The testes, nine pairs of small white glandular bodies situated close to the nerve cord. The first pair are in the fourth somite behind that which contains the penis, and the others are in the eight following somites, a little in front of the segmental organs.

6. The female reproductive organs. These are in the somite next behind that which contains the penis, and are made up of: —

(i.) The vagina; a muscular sac upon the median line.

(ii.) The twisted oviduct running from the top of the vagina. It soon divides into two branches which run down towards the ventral surface, and terminate in the small white ovaries.

7. In the segment next behind that which contains the female organs, notice the two pairs of white convoluted mucous glands.

8. Make a sketch showing the reproductive organs in place.

9. The nervous system. This consists of: —

(i.) A double commissural cord, which runs from one end of the body to the other, and consists of two fibres which lie side by side in a common sheath for the greater part of their length.

(ii.) The series of twenty-one ganglia.

(*a.*) The first of these is the largest, and gives off five pairs of nerves.

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(*b.*) The remaining ganglia, except the two last, give off two nerves each on each side.

(*c.*) The most posterior ganglion but one gives rise to only one pair of nerves.

(*d.*) The last ganglion is much larger than those which immediately precede it, and gives off seven pairs of nerves.

(iii.) Anterior to the first ventral ganglion the two commissural fibres diverge from each other and bend up around the anterior end of the pharynx to form the *mouth-ring*. On the upper surface of the anterior end of the pharynx they end in, —

(iv.) The *supra-œsophageal ganglion*, or *brain*, composed of two halves meeting in the median line.

(*a.*) Each half of the brain gives rise to five optic nerves, which pass to the eye-spots of that side of the body.

(*b.*) The brain is also united to the three *stomato-gastric* or sympathetic ganglia; one on each of the three muscular lobes of the buccal pouch. One of these ganglia lies in the median line in front of the brain, and is united at each end to one-half the latter. The other two are upon the sides, and each joins the corresponding half of the brain.

III. The Mouth. This may now be examined in the dissected specimen. By bending up the upper lip the triangular opening of the mouth may be seen at the bottom of the cavity of the anterior sucker. The ventral slit is vertical, and the two dorsal slits are inclined towards it so as to form a Y. Open the buccal cavity by a cut along one of the slits, and notice the three large white buccal muscles which occupy the spaces between these grooves or channels, of which the three slits are the external ends. In the medicinal leech the teeth are placed upon the inner surfaces of these muscles.

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XVIII.—THE STUDY OF THE HARD PARTS OF THE COMMON CRAB.

(*Callinectes hastatus.*)

A STUDENT of the elements of Morphology can hardly grasp the significance of the structure of the Decapod Crustacea until he has studied several forms, and as excellent directions for studying the crayfish or lobster are within the reach of most students, it seemed best to describe some other type here. If the student has verified the description of the crayfish or lobster which is given by Huxley, Packard, or Huxley and Martin, the study of a crab will serve as a review, and will throw new light upon the significance of the facts. For the benefit of those students who have not gone over this ground, I shall give, in the next section, a brief description of the hard parts of the lobster, and a lobster or a crayfish should, if possible, be examined at the same time that the crab is studied.

If squilla can be procured, it should also be examined at the same time, but as it is not readily procurable, I give no description of it.

The common edible crab may be found in abundance in all the inlets, bays, and sounds of our southern coast; and as it may also be obtained, during the winter, in the markets of our larger cities, it is a good form to select for laboratory work. If it cannot be procured, any other crab will answer nearly as well, and most of the points may be verified in the common shore crab (Cancer irroratus) of the New England coast. This latter crab may be collected in the crevices of rocks near low tide mark, and

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it may be preserved in alcohol, or studied while fresh. If specimens are to be preserved for winter work, they should be bled before they are placed in alcohol. This is done by puncturing the soft integument of the dorsal surface between the posterior edge of the carapace and the first abdominal somite. They should then be placed in eighty or eighty-five per cent alcohol, which should be renewed in four or five days. Specimens for studying the hard parts may be dried in the sun.

I. The *Dorsal Surface.*

The dorsal surface of the body is almost entirely covered by the *carapace*, which, in Callinectes, is about three times as wide as it is long; irregularly rhomboidal, with its outer angles prolonged into two sharp-pointed, projecting horns. Observe: —

a. The anterior, nearly semicircular, serrated margin.

1. The middle of this margin is marked by a concave notch, beneath which a short spine projects from the middle line of the body. The spine does not form part of the carapace, but is attached to the ventral or *sternal* portion of the antennary somite.

2. On each side of the spine notice that the *antennules* project beyond the overhanging edge of the carapace.

3. Outside these, on the edge of the carapace, the median pair of serrations. This pair of serrations, together with the notch between them, represent the protruding *rostrum* of the lobster or the crayfish.

4. The next pair of serrations are rounded, and overhang the antennæ, and outside them, on each side, is an area, free from teeth, below which is the *eye.*

5. The edge of the carapace, between this space and the outer angle, is occupied by eight serrations, which are nearly alike in size and shape.

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b. The posterior margin of the carapace is divided into a median and two lateral portions. It carries no large serrations, but a very finely dentated ridge runs parallel to and very near its edge.

c. The dorsal surface of the carapace is mapped out by depressions into several areas.

1. On the dorsal median line, somewhat nearer the posterior than the anterior end, there is a transverse depression, about half an inch long, the outer ends of which unite, at an obtuse angle, with two straight depressions, which run forwards and outwards, to unite anteriorly with two lines which run outwards on to the horns at the lateral angles of the carapace.

This system of depressions appears to be homologous with the cervical suture of the crayfish or lobster, and divides the carapace into an anterior *cephalic*, and a posterior *thoracic* area.

(i.) The thoracic area is again divided, by a pair of faintly marked depressions, running from the outer ends of the transverse bar of the cervical suture to the edges of the carapace, over the last pair of legs, into a central *cardiac*, and two lateral *branchial* areas.

(ii.) The cephalic area is divided into the following regions:

(*a*.) An irregular transverse depression, crossing the middle of the carapace near its anterior edge, and bending forward at its ends to meet the anterior edge over the eyes, marks of an anterior or *facial* region, which is again divided into a median *frontal lobe*, and two *orbital* lobes.

(*b*.) The space between the facial depression and the cervical suture is divided by two longitudinal furrows into a large, median, sub-triangular, *gastric* region, and two *hepatic* lobes.

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The hepatic lobes are bounded externally by the serrated anterior margin of the carapace, posteriorly by the cervical suture, and internally by the gastric area and optic lobes.

(*c.*) Posterior to the carapace, the dorsal or *tergal* surface of the first abdominal ring or *somite* is visible in a dorsal view.

d. Make a sketch of the dorsal aspect, showing all these points.

II. The *Ventral Surface.*

On the median line of the posterior portion of the ventral surface, notice the abdomen (Fig. 91, *ab*), which is bent downwards and forwards, so that its ventral surface faces upwards, and is in contact with the ventral wall of the thorax, while its dorsal surface faces downwards, and is external. The abdomen fits into a groove or depression in the ventral wall or *sternal plastron* of the thorax, and presents considerable sexual variation.

a. In the male (Figs. 91 and 103, *ab*), it is narrow and wedge-shaped, and fits closely into its groove. Raise it up with the handle of a scalpel, and notice the two teeth by which it is locked into place.

b. The abdomen of the female (Fig. 102, *ab*), is broad and rounded, and its inner or ventral surface is concave, thus forming a broad chamber for containing and protecting the developing eggs. It consists, in the female, of six flattened, movable rings, or somites, which are calcified and hard upon their exposed or dorsal surfaces, and soft and membraneous on their internal or ventral surfaces.

1. The first, second, third, and fourth abdominal somites of the female carry paired appendages, the *pleopods* (Fig. 102, *pl*). Each appendage is fringed with long hairs, to which, during the breeding season, the eggs are fastened, and consists of: —

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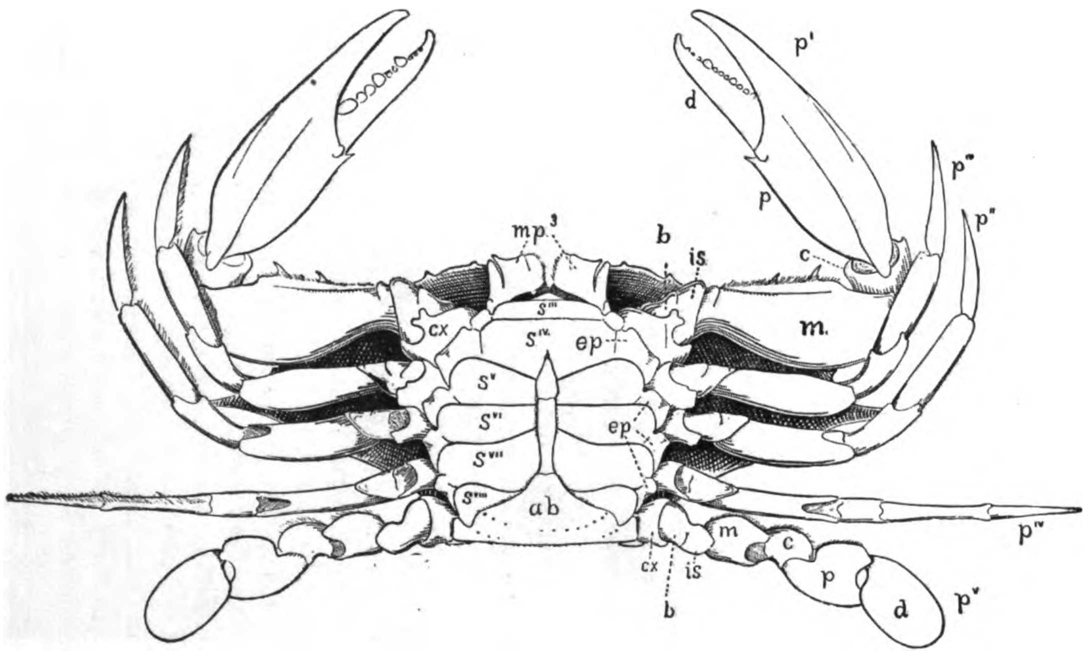

Fig. 91.

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FIG. 91. — Ventral surface of male specimen of Callinectes hastatus. (Drawn from nature by W. K. Brooks.]

ab. Abdomen. *b.* Basipodite. *c.* Carpopodite. *cx.* Coxopodite. *d.* Dactylopodite. *ep.* Episterna. *is.* Ischiopodite. *m.* Meropodite. mp^3. Third maxillipeds. s^{iii} — s^{viii}. Sterna of thorax. p^1 — p^5. The five pairs of pereiopods. *p.* Propodite.

(i.) An oblong basal joint, or *protopodite*, which runs backwards and forwards, and carries two long, slender, terminal filaments.

(ii.) The inner one of these, the *endopodite*, is attached to the inner margin of the protopodite close to its distal end.

(iii.) The outer one, or *exopodite*, is attached to the outer margin of the protopodite near its proximal end.

2. Straighten out the abdomen of the female, and notice that its dorsal or external surface is continuous with the carapace, while its soft, internal surface is continuous with the ventral surface of the body. Separate the second abdominal somite, and having cleaned out the soft parts, examine it from one end, and notice: —

(i.) The broad, hard, slightly-arched, dorsal surface, or *tergum*.

(ii.) The two lateral flaps, or *pleura*, which project from the sides of the tergum, beyond the outline of the ventral surface.

(iii.) The soft, membraneous, ventral portion, or *sternum*, much shorter from side to side than the tergum. Notice the point where the appendage is attached, between the tergum and the sternum. The sternum is usually regarded as consisting of three portions, a median true sternum, with an *episternum* on each side, between the true sternum and the base of the limb, but no such division can be seen in the sternum of the abdominal somite of a crab.

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(iv.) The portion of soft integument which lies between the joint of the appendage and the tergum is the epimeron. This can hardly be recognized in the abdomen of the crab.

c. The male abdomen (Figs. 91 and 103, *ab*), is made up of four pieces. The first corresponds to the first in the female abdomen; the second is formed by the fusion of the second, third, and fourth rings; while the third corresponds to the fifth in the female, and the fourth to the sixth.

d. The male abdomen carries only two pairs of appendages, modified to form copulatory organs.

e. In both sexes, the *anus* is placed upon the sternal surface of the last abdominal somite.

f. Make sketches of the male and the female abdomen, showing these points.

g. The *Sternal Plastron.*

This is the broad, shield-shaped ventral skeleton of that portion of the body which lies between the basal joints of the five pairs of legs. Its surface is excavated in the middle line for the reception of the abdomen. It is made up of the united sterna and episterna of a number of somites.*

1. On its exposed surface notice five distinct sutures or folds; the lines of union between the posterior six of the eight sterna (Fig. 91, s^{i}–s^{viii}), which enter into it.

2. Wedged in between the outer ends of these sterna, notice the *episterna* of the corresponding somites; each

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* As the critical discussion of disputed points would be out of place in this work, I have followed Milne Edwards in this description. His terminology is the one which the student will meet in text-books and lectures, and it does not seem advisable to create confusion by changes, which, to the beginner, would seem arbitrary and meaningless.

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episternum (Fig. 91, *p*), being anterior to the outer end of its own sternum, and articulating with the basal joint of an appendage.

h. The *Appendages.*

Six pairs of appendages, the third pair of Maxillipeds (Fig. 91, $m\ p^3$), and five pairs of legs, or *pereiopods*, (p^1, p^2, p^3, p^4, p^5), are articulated around the lateral and anterior margins of the sternal plastron.

1. The third maxillipeds (Fig. 91, mp^3, and Fig. 92), meet upon the median line in front of the anterior angle of the sternal plastron, and they are flattened so as to form a square operculum, which covers the more anterior mouth parts.

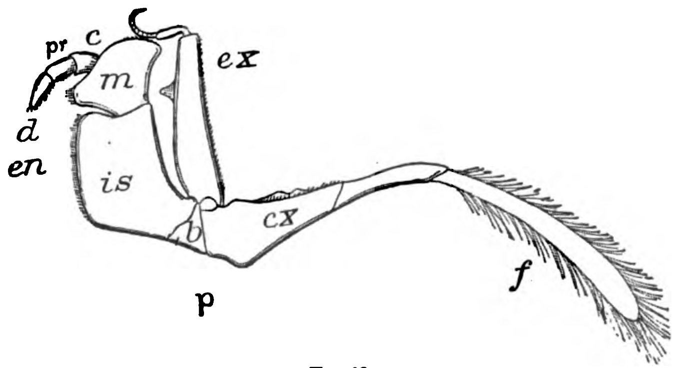

FIG. 92.

FIG. 92.—Outer surface of left third maxilliped of Callinectes hastatus; natural size. (Drawn from nature by W. K. Brooks.)

p. Protopodite. *en.* Endopodite. *ex.* Exopodite. *f.* Flabellum. *b.* Basipodite. *cx.* Coxopodite. *is.* Ischiopodite. *m.* Meropodite. *c.* Carpopodite. *pr.* Propodite. *d.* Dactylopodite.

Like the abdominal appendage, or pleopod, this appendage is divisible into three regions, a *protopodite* (Fig. 92, *p*), an *exopodite* (Fig. 92, *ex*), and an endopodite (Fig. 92, *en*), but each of these regions is again divided into parts.

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(i.) The protopodite (p) is obscurely divided into two joints. The proximal one, articulating with the sternal plastron, is known as the *coxopodite* (c) and the distal one as the *basipodite* (b). The protopodite carries, besides the exopodite and the endopodite, a long, hairy process, the *flabellum*, or epipodite (Fig. 92, f). In order to expose the flabellum, the appendage must be removed from the body.

(ii.) The *exopodite*, (Fig. 92, *ex*), is long and slender, and divided into two portions, the distal one being obscurely many-jointed.

(iii.) The *endopodite* (Fig. 92, *en*), is divided into two regions, a proximal, greatly flattened, two-jointed region, or *gnathostegite*, and a terminal, three-jointed, slender, finger-like process, the *endognathal palp*.

(iv.) The large, flattened, basal joint of the gnathostegite (Fig. 92, *is*), is the *ischiopodite*, and the smaller terminal joint (m) is the *meropodite*.

(v.) The basal joint (c) of the endognathal palp, is the *carpopodite;* the middle joint (*pr*) the *propodite*, and the terminal joint (d) the *dactylopodite*.

2. The *Pereiopods*.

The five pairs of legs, or pereiopods, are quite similar in structure. Each consists of a two-jointed protopodite, and a long, five-jointed limb, or endopodite; the exopodite being absent. The seven joints which make up the limb are then the basipodite (Fig. 91, p) [*see foot-note on p.* 174], coxopodite (*cx*), ischiopodite (*is*), meropodite (m), carpopodite (c), propodite (p), and dactylopodite (d). The joint between the second and third portions, the ischiopodite, and coxopodite, admits of very little motion, and the two pieces are almost fused with each other.

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(i.) The first pereiopod is much larger and stronger than any of the others, with serrations along its anterior edge, and the tip is colored bright blue in the male, and red in the female. The distal end of the propodite is prolonged forwards as a finger-like process, which, lying parallel to the dactylopodite, forms the *chela*, or claw. The opposed edges of the halves of the claw are set with tooth-like serrations, and these are round and blunt in one claw, sharp and pointed in the other.

(ii.) The second, third, and fourth pereiopods are very like each other, shorter than the first, and without chelæ.

(iii.) The fifth pereiopod has its terminal joints flattened, and fringed with hairs, and is a paddle-shaped swimming organ.

(iv.) On the inner ventral edge of the coxopodite of the fifth pereiopod of the male, notice a delicate membraneous tube, the projecting tip of the vas deferens. It passes into the base of the first abdominal appendage.

i. The female reproductive orifices are covered by the abdomen, and are near the middle line on the sternum of the somite which carries the third pair of pereiopods.

j. In front of the coxopodite of the first pereiopod, notice a large aperture through which the water passes to the gills. Move the third maxilliped, and notice that its flabellum runs backwards and outwards from the protopodite into this cavity.

k. Outside and anterior to the bases of the appendages, the outline of the body is completed by the reflected ventral portion of the carapace, on the anterior margin of which are the *eyes*, the *antennules*, and the *antennæ*.

l. Make a drawing of the ventral aspect, showing all these points.

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III. The *Appendages.*

Having removed the abdomen, carefully disarticulate its appendages, and the five pairs of pereiopods, and lay them aside in order, for subsequent examination. Raise up and disarticulate the third maxillipeds, and carefully remove them, with their long flabella.

a. Under these notice the second and first pairs of maxillipeds, much like the third pair, but more soft and membraneous. Disarticulate the second maxilliped, and removing it for examination, notice that it consists, like the third maxilliped, of: —

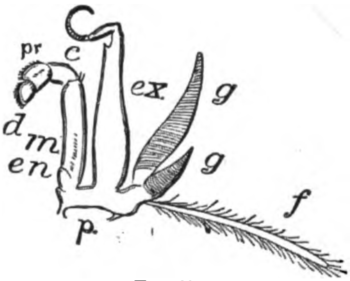

FIG. 93.

(i.) A two-jointed protopodite (Fig. 93, *p*), which carries two gills (*g*), and an epipodite, or flabellum (*f*).

FIG. 93. — Outer surface of left second maxilliped; natural size. (Drawn from nature by W. K. Brooks.)

g, *g*. Gills. Other letters as in Fig. 92.

(ii). A long, slender exopodite (*ex*), much like that of the third maxilliped.

(iii.) A five-jointed endopodite (*en*), which is not flattened to form an operculum, as in the third pair.

b. Remove the first maxillipeds, and examining them, notice that, while they have a close resemblance to the others, they are soft and foliaceous (Fig. 94), and without gills. The flabellum (*f*) and exopodite (*ex*) are much like those of the second and third maxillipeds, but the two joints of the protopodite, the basipodite (*b*) and the coxopodite (*ex*) are greatly enlarged to form two hairy jaws, on each side, while the endopodite (*en*) is unjointed, soft, membraneous, and fused with the exopodite.

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c. Notice now on each side of the rectangular mouth area, or *peristome*, a large orifice which communicates with a capacious chamber under the carapace.

This chamber is the branchial chamber, and the aperture is that through which the water passes *from* the gills. Lying in the mouth of this aperture, notice a thin, membraneous, spoon-shaped scoop, the *scaphognathite*, by the movement of which, during life, the water is bailed out of the branchial chamber.

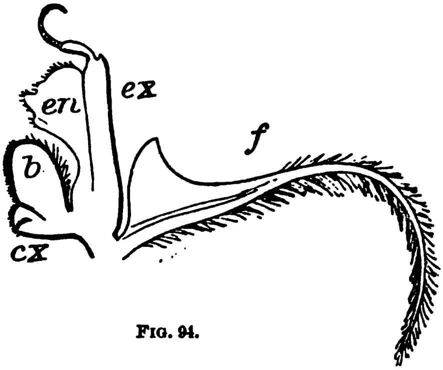

FIG. 94.

FIG. 94. — Outer surface of left first maxilliped; natural size. (Drawn from nature by W. K. Brooks.)
Letters as in Fig. 92.

d. Raise up the edge of this scoop, and notice that it is part of a thin, membraneous appendage, the *second maxilla* (Fig. 95).

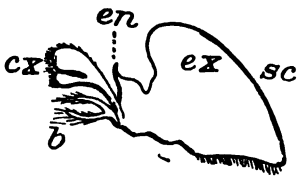

FIG. 95.

FIG. 95. — Outer surface of second maxilla; natural size. (Drawn from nature by W. K. Brooks.)
sc. Scaphognathite. Other letters as in Fig. 92.

Remove this appendage for examination, and notice that the two divisions of the protopodite (*b*) and (*cx*) are elongated, bilobed, and hairy. The lobes of the basipodite (*b*) are long and slender, while those of the coxopodite are more rounded. Outside these notice a short, pointed, hairy process (*en*), which is the rudimentary

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endopodite. The remainder of the appendage forms the flattened scaphognathite (*sc*), which is, probably, a modified exopodite.

e. After removing the second maxillæ, notice under them the still more delicate and foliaceous *first* maxillæ (Fig. 96). Remove these, and notice that the basipodite (*b*) and the coxopodite (*cx*) are very much elongated and jaw-like, while the exopodite is absent, and the endopodite (*en*) is very small, but not quite as rudimentary as that of the second maxilla.

FIG. 96.

FIG. 96. — Outer surface of left first maxilla; natural size. (Drawn from nature by W. K. Brooks.)
Letters as in Fig. 92.

f. Notice the cutting edges of the mandibles, which meet each other on the middle line. Force them apart, and notice between them the mouth, with its membraneous, hairy upper lip, with several small calcifications, and just posterior to the cutting edges of the mandibles notice on each side of the middle line of the body a spatulate process which runs downwards and lies in contact with the surface of the mandible. These two processes form the *metastoma*, or lower lip. Each consists of a calcified rim or frame, covered by a soft membrane.

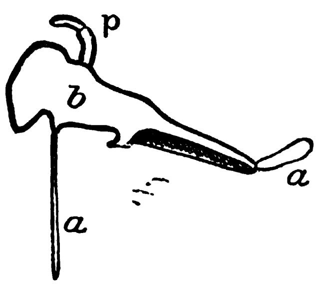

FIG. 97.

FIG. 97. — Outer surface of left mandible; natural size. (Drawn from nature by W. K. Brooks.)
a, a. Apodemata. *b.* Body of Mandible. *p.* Mandibular palpus.

Remove the mandibles, and, examining them, notice that

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each consists of a dense, solid body (*b*), and a movable, two-jointed portion (*p*). The body is the basal joint or basipodite, which is greatly thickened and elongated, and which carries a stout, cutting blade upon its inner end. The two-jointed portion (*p*) is the *mandibular palp*. It bears a general resemblance to the endopodite of an ordinary appendage, but its mode of development, which will be noticed later, has induced most authorities to regard it as without an homologue in a typical appendage, and according to this view the mandibular endopodite is absent, as well as the exopodite. Near the ends of the mandible notice two plates, or *apodemata*, which run inwards, and furnish attachment for the mandibular muscles.

g. The remaining appendages are arranged in a longitudinal row along the anterior margin of the carapace; the *antennules* in the centre, the *eyes* on the outside, and the *antennæ* between the eyes and the antennules.

1. The antenna (Fig. 98) consists of an enlarged, irregular basal joint (*a*), which is so firmly fastened to the shell that it admits of hardly any motion, and which carries a hairy spine (*b*); and a slender terminal portion, or flagellum (*c*), which consists of two long basal joints, and a great number of short rings.

FIG. 98.

FIG. 98. — Outer surface of left antenna of Callinectes hastatus; natural size. (Drawn from nature by W. K. Brooks.)

a. Basal joint. *b*. Spine. *c*. Flagellum.

FIG. 99.

FIG. 99. — Outer surface of left antennule of Callinectes hastatus; natural size. (Drawn from nature by W. K. Brooks.)

a. Basal joint. *b*. Shaft. *c*. Flagella.

Carefully disarticulate the antennæ, and place them with the other appendages.

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2. The antennules (Fig. 99) consist of a large, hairy, basal joint (*a*), which is freely movable, and which carries a large, two-jointed shaft (*b*), which ends in two small, many-jointed flagella (*c*).

Carefully disjoint the antennules, and examining the inner surface of the basal joint, notice a longitudinal slit, covered with hairs, and completely closed. This slit marks the position of the external opening of the ear in the young. In the adult crab it is closed, although it remains permanently open in the lobster or crayfish.

3. Outside the antennæ are the large, movable, stalked, compound eyes. Raise them up and disjoint them, and place them with the other appendages.

h. Study and compare the appendages. Each pair of appendages is carried by a region of the body which may, in certain crustacea, be represented by a distinct ring or somite, and a crustacean is therefore regarded as consisting of as many somites as there are pairs of appendages.

The series of somites and appendages is therefore as follows: —

1. Occular segment. Eyes. (This is not the proper place for an examination of the question whether the eyes are or are not homologous with the other appendages. I have here followed the older writers, but not without careful revision of the subject.)
2. Antennulary somite. Antennules. Auditory Organs.
3. Antennary somite. Antennæ.
4. Mandibular somite. Mandibles.
5. Metastoma.
6. First maxillæ.
7. Second maxillæ.

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8. First maxillipeds.
9. Second maxillipeds.
10. Third maxillipeds.
11. First pereiopods, chelate.
12. Second pereiopods.
13. Third pereiopods. The oviducts open upon the sternal portion of this somite.
14. Fourth pereiopods.
15. Fifth pereiopods, swimming organs, with male reproductive orifices on their basal joints.

16. First	abdominal	somite.	First pleopods.
17. Second	"	"	Second pleopods.
18. Third	"	"	Third pleopods, absent in male.
19. Fourth	"	"	Fourth pleopods, absent in male.
20. Fifth	"	"	Appendages absent.
21. Sixth	"	"	" "

i. Draw the appendages, in their natural order.

IV. On the ventral surface of the specimen from which the appendages have been removed, notice that the carapace is reflected inwards along the sides, as far as the bases of the legs, so that the opening by which water passes under the carapace to the gills is a small, crescent-shaped slit in front of the first pereiopod. Anterior to the pereiopods, the lower surface of the carapace forms the straight, longitudinal borders of the peristome.

The anterior border of the peristome is formed by the *antennary sternum*, or *epistoma*, which carries a projecting median spine, and is joined to the overhanging edge of the carapace by the *median rostral septum*.

V. The *sternal plastron* may now be removed, and cleaned for examination.

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a. On its dorsal surface notice the eight pairs of laminated, pyramidal gills. The first pair are small and horizontal, while all the others are vertical. The first and second pairs are attached to the bases of the second maxillipeds. The third pair lie over the bases of the third maxillipeds, and the remaining five pairs lie above the bases of the five pairs of pereiopods. Notice that each gill consists of a series of plates or leaflets, connected by an external tube, the vessel which carries venous blood to the gills, and an internal tube, the vessel which carries the aerated blood away from the gills. Remove the gills, and clean out the muscles which fill the deep, honeycomb-like cells of the sternal plastron.

b. This is now seen to be a complicated hollow box, divided, by great numbers of partitions, into irregular cells. It is made up of the sternal, episternal, and epimeral portions of the somites which carry the appendages between the first pair of maxillipeds and the last pair of pereiopods.

1. The united *sterna* form the smooth, external surface.

2. The outer or ventral ends of the *episterna* are visible externally, wedged in between the outer ends of the sterna. They are continued upwards towards the dorsal surface as thin plates between the muscle chambers of adjacent somites.

3. The united *epimera* form the sloping dorsal surface, the *flancs*, upon which the gills rest, and they also send plates down to complete the partitions between the muscle cells.

4. Make sketches of the ventral and lateral aspects of the sternal plastron.

VI. Clean the carapace, and, on the inner surface of the anterior edge notice the attachment of the eyes, anten-

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nules, and antennæ. In this view, it is plain that the eyes are the first, or most dorsal pair of appendages, the antennules next, and the antennæ third. This arrangement is obscured, on the outer surface, by the great size of the eyes, in accordance with which these appendages have pushed the second and third pairs towards the middle line of the body.

XIX.—THE HARD PARTS OF THE CRAYFISH OR LOBSTER.*

I. The body is divided into two well-marked regions,—the anterior, unsegmented portion, or *cephalothorax*, to the lower surface of which the walking limbs are attached; and the more narrow, posterior portion, or abdomen, which is divided into seven movable portions or joints. In a view of the dorsal surface, notice:—

a. The great shield-like plate, or *carapace*, which covers the back and sides of the cephalothorax.

b. The groove, or *cervical suture*, which divides it into an anterior and a posterior region.

c. The long spine, or *rostrum*, situated upon the median line of the anterior margin of the carapace.

d. The stalked eyes, and long, many-jointed antennules and antennæ, which project from below the anterior margin of the carapace, on each side of the rostrum.

e. The five pairs of long, jointed, walking limbs, which project from below the sides of the carapace.

f. The dorsal surfaces, or *terga*, of the segments of the abdomen.

1. The first, second, third, fourth, fifth, and sixth of

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* This section is copied, with slight changes, from "Biology," by Huxley and Martin.

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these are substantially alike, and consist of an anterior, smooth, highly-polished portion, which is overlapped by the posterior margin of the preceding segment, and a rougher, posterior portion, the posterior margin of which projects over the anterior margin of the succeeding segment.

2. The seventh, or terminal joint of the abdomen, the *telson*, is a flattened, somewhat triangular plate.

3. At the sides of the telson are the paddle-shaped *swimmerets*, the appendages of the sixth abdominal segment.

g. Make a sketch of the dorsal surface, showing all these points.

II. The ventral surface.

a. Notice the lateral edges of the carapace, the rostrum, eyes, antennules, and antennæ, as before.

b. Back of these, the complicated mouth parts, meeting each other on the median line.

c. Push these apart, and notice between them the aperture of the mouth.

d. Back of the mouth parts are the five pairs of walking legs.

e. Between the basal joints of each pair is a plate, the *sternum*, or ventral portion of the segment, to which the pair of limbs is attached. The sterna which correspond to the first four pairs of limbs are immovably united to each other, while the fifth is slightly movable.

f. Along the outer edges of the ventral faces of the abdominal segments are the thin, flat, swimming feet, varying somewhat in number and form, according to the sex.

g. The swimming feet of the sixth abdominal segment are much larger than the others, and are the swimmerets which are visible in a dorsal view.

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h. The narrow sterna of the abdominal segments, between the bases of the swimming feet.

i. The anus, in the soft integument of the lower surface of the telson.

k. Note that the sternal surface which carries the eyes, antennules, and antennæ, makes a sharp angle — the cranial flexure — with the sterna of the remaining segments.

l. Make a sketch showing these points.

III. Removing the third abdominal segment, with its appendages, notice: —

a. The arched dorsal surface of the segment, the *tergum*.

b. The flaps, or lateral walls, pleura of the tergum. The posterior margin of each pleuron overlaps the smooth, anterior margin of the succeeding pleuron.

c. The narrow sternum, forming that portion of the ventral surface which lies between the appendages.

d. The flexible membrane which covers the space between the sterna of adjacent segments.

e. The point of union of the appendage with the segment.

f. The *epimera*, or those portions of the ventral surface which lie external to the points of attachment of the appendages. The epimera are very short, and pass almost directly into the inner walls of the pleura.

g. The appendages or pleopods of the third abdominal segment consist of: —

1. A short, two-jointed, basal portion, or *protopodite*, consisting of a shorter proximal, and a longer distal piece.

2. Two flattened plates, an outer *exopodite*, and an inner *endopodite*, attached to the distal end of the *protopodite*.

h. Make a sketch of the segment, showing all these points.

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i. The fourth and fifth abdominal segments closely resemble the third.

j. The appendages or swimmerets of the sixth abdominal segment are very large, and are made up of —

1. A protopodite, which consists of a single, short, strong joint.

2. A wide exopodite, fringed with long hairs, and divided into two portions by a transverse joint.

3. A triangular endopodite, also fringed with long hairs.

k. Make a sketch of this appendage.

l. The second abdominal segment of the female is much like the third, and carries a pair of ordinary pleopods, and the appendages of the first abdominal segment of the female are rudimentary.

m. In the male, the protopodite and endopodite of the appendage of the second abdominal segment are elongated and rolled up so as to form an imperfect tube.

n. The first abdominal appendage of the male is a single plate, rolled into a tube, and lying in the groove upon the second appendage.

o. The terga of all the segments anterior to the first abdominal, are represented, or at least replaced by, the carapace, which is made up of a median dorsal area, and two lateral folds, or *branchiostegites*, which lie above the bases of the pereiopods. Raise up the margin of this fold, and notice the branchial cavity which lies below it. Carefully cut away the fold from one side of the body, and notice the plume-like gills.

p. Examine and remove the remaining appendages from one side of the body, in the order in which they are described, and place them in their natural order for examination.

1. The walking legs, or pereiopods, are made up of

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seven movable joints, working in different planes, so that the limb, as a whole, can move in any direction.

2. The mouth parts; the most posterior pair of mouth parts — the *third maxillipeds* — cover those anterior to them, and must be removed in order to expose the latter.

3. The third *maxilliped* consists of a basal, two-jointed protopodite, and three terminal portions.

(i.) The *epipodite*, which is a long, curved plate, which extends into the branchial chamber, and carries a gill.

(ii.) A long, slender, many-jointed exopodite.

(iii.) A thicker-jointed endopodite.

4. The *second maxilliped* is much like the first, but its endopodite is less stout.

5. The *first maxilliped*, much more slender, and smaller; its endopodite is flattened and foliaceous; and the epipodite is a simple plate.

6. The two pairs of maxillæ, and the mandibles, are so much like those of the crab, that it is hardly necessary to describe them.

7. After the mouth parts have been removed, notice the mouth, and, projecting forward over it from its posterior margin, the oval *metastoma*, covered with short, stiff hairs.

8. Anterior to the mouth, the large *antennæ*, each of which consists of: —

(i.) A two-jointed protopodite.

(ii.) A long, multi-articulate endopodite.

(iii.) A flattened, scale-like exopodite.

(iv.) On the lower surface of the basal joint of the protopodite, notice the opening of the antennary gland.

9. The much smaller *antennulæ;* each of which is made up of a pair of jointed filaments, mounted upon a long protopodite.

10. On the flat upper surface of the protopodite notice

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a row of hairs which cover a small slit, the opening of the *auditory* organ.

11. The large eyes, mounted at the tips of movable cylindrical eyestalks.

12. Make sketches of the series of appendages.

XX. THE GENERAL ANATOMY OF A CRAB.

(*Callinectes hastatus.*)

Either fresh or alcoholic specimens may be used for dissection; but if fresh specimens are used, the various parts may be rendered more conspicuous by covering the specimen with alcohol after it has been opened. All the dissecting should be done under water or alcohol.

I. General Anatomy.

Select if possible a large female specimen; kill it by bleeding; and open it by carefully cutting away the dorsal portion of the carapace, taking care to avoid injuring the internal organs.

a. In the specimen thus opened notice the tough, dark-colored skin, which lies just inside the shell and lines it. Cut away this skin or turn it out and notice: —

b. The large transparent *stomach* (Fig. 100, *e*) which occupies the middle of the anterior half of the cavity of the shell. It is pear-shaped in surface-view, with its anterior end broadest. Notice that the outer ends of the anterior border are prolonged into a pair of horn-like processes, which are attached by muscular fibres to the inside of the anterior edge of the carapace, behind the orbital notches.

c. A pair of calcified rods, the *pterocardiac ossicles* (Fig. 100, *b*) lie transversely across the dorsal surface of

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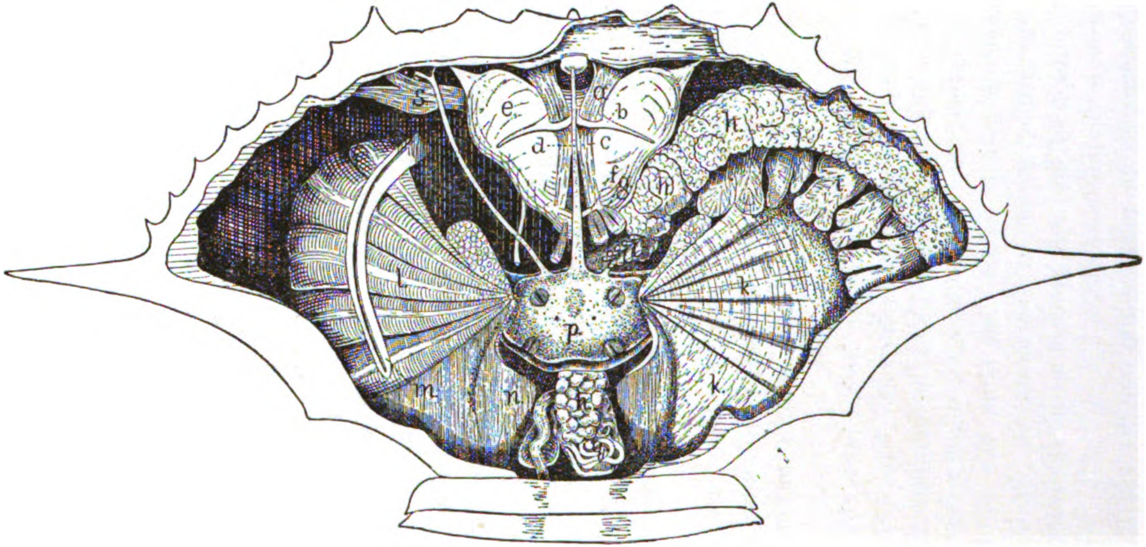

FIG. 100.

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Fig. 100. — A female specimen of Callinectes hastatus, with the carapace removed, showing the viscera in place on the right side, but partially dissected on the left side. (Drawn from nature by W. K. Brooks.)

a. Anterior gastric muscles. *b.* Pterocardiac ossicle. *c.* Middle gastric muscles. *d.* Ophthalmic artery. *e.* Stomach. *f.* Pyloric ossicle. *g.* Posterior gastric muscles. *h.* Ovary. *i.* Liver. *k.* Branchial chamber. *l.* Gills. *m.* Flabellum. *n.* Flancs. *p.* Heart. *q.* Intestinal coecum. *s.* External mandibular muscles.

the stomach. They are on the inside of the stomach, but their opacity renders them conspicuous in a surface view.

d. A "*pyloric*" *ossicle* (Fig. 100, *f*) lies in the dorsal wall of the stomach, near its posterior end.

e. Notice the *anterior gastric muscles* (Fig. 100, *a*) which run from the inner ends of the "cardiac" ossicles to the anterior edge of the carapace.

f. The *middle gastric muscles* (Fig. 100, *c*), running from the "cardiac" to the "pyloric" ossicle.

g. The *posterior gastric muscles* (Fig. 100, *g*) which run outwards and upwards from the "pyloric" ossicles to the gastric region of the carapace.

h. A little posterior to the ends of these muscles notice the enlarged ends of the internal mandibular muscles, which are also attached to the gastric region of the carapace.

i. On the middle line of the body above the stomach notice the median, or *ophthalmic artery* (Fig. 100, *d*).

j. Follow this backwards to about the middle of the body, where it enters the *pericardium*, a slightly transparent membraneous pouch, which lies upon the middle line, under the cardiac region of the carapace. If the animal be not quite dead the slow pulsations of the heart may be seen through the pericardium.

k. Posterior to the pericardium, on the middle line of the body, there is a hollow, somewhat below the level

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of the surrounding organs. This hollow usually contains, in the female, a portion of the orange-yellow ovary (Fig. 100, *h*), and underneath this the tubular, transparent, convoluted, intestinal coecum (Fig. 100, *q*), which consists of two portions, — a long, very small tube, which is twisted into a compact ball, a little to the right of the middle line, and a larger portion which is nearly straight, and runs backwards on the left of the middle line, into the first segments of the abdomen, where it opens into the intestine.

l. Below the intestinal coecum, portions of the light grayish-yellow *liver* may usually be seen; and if the posterior free ends of all these organs are gently raised up, the transparent, straight intestine may be seen running backwards into the abdomen on the middle line below them.

m. These organs and the pericardium are bounded laterally by elevations which reach nearly to the dorsal carapace, and are encased in a hard, white, calcified shell. They are known as the *flancs* (Fig. 100, *n*), and they contain the muscles of the pereiopods. Their inner edges are nearly vertical, and form the walls of the depression for the heart and intestinal coecum, while their outer surfaces slope gently downwards and outwards.

n. The outer sloping surface of each flanc is covered by the tough, transparent chitinous wall (Fig. 100, *k*) of the branchial chamber, through which the long, pyramidal gills (Fig. 100, *l*) are visible. Turning the specimen over, introduce a small tube into the crescent-shaped opening at the base of the third maxilliped, and blow air through the tube into the opening. Turn the specimen over again, and notice that the air has passed into the branchial chamber, between the gills (*l*) and the roof (*k*).

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The branchial chamber is thus shown to open externally, and its manner of development shows that it is entirely external to the body cavity, and is formed by an infolding of the shell, and its transparent roof (*k*) will be found to be continuous, at each edge, with the ordinary calcified shell which covers the rest of the body. Notice that the branchial chamber runs back onto the flancs for some distance beyond the most posterior gill, and that there is a flat, muscular band along its edge.

o. The space between the stomach in front and internally, the pericardium posteriorly, and the flancs and branchial chamber externally, is occupied by the orange *ovaries* (Fig. 100, *h*), which run forwards and outwards along the sides of the stomach, to the anterior margin of the carapace, and then backwards and outwards, along the carapace, as far as the bases of its large lateral horns. The character and size of the ovary varies considerably according to the season, and in the late summer months, after nearly all the eggs have been laid, it is usually much smaller than it is shown in the figure, which was drawn from a specimen which was caught in the winter.

p. A branch (*i*) of the *liver* also takes nearly the same course, and runs outwards along the side of the stomach and the anterior edge of the carapace. It is below the ovary, but as it is a little wider, the inner or free ends of the lobules into which it is divided are visible between the ovary and the bases of the gills.

q. Make a drawing showing all these organs, in place, as seen in a surface view.

r. The *heart*. Cut open the pericardium and expose the heart (*p*) in place. It is a white, fleshy, somewhat hexagonal organ, which lies in the cavity of the pericardium, to the walls of which it is loosely attached. Near

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its anterior edge notice a pair of circular, transparent depressions, each of which is crossed by a transverse slit or opening into the heart. These slit-like openings are the *ostia*, by which the blood passes from the cavity of the pericardium into the heart, and the transparent semicircular flaps are valves, which allow the blood to flow into the heart, but prevent it from passing back into the pericardium. On the posterior edge of the heart notice two more ostia, similar to those near the anterior border.

1. At the anterior external angles of the pericardium notice the *sinuses* by which the blood from the gills enters it, to pass into the heart.

2. Notice the ophthalmic artery (Fig. 100, *d*) which runs forwards from the middle line of the anterior border of the heart.

3. On each side of this artery a hepatic artery (dissected out on the left side of Fig. 100) passes through the mandibular muscle to the ovary, the liver and anterior edge of the carapace, and the antennæ.

4. A small *abdominal artery*, not shown in the figure, runs backwards from underneath the posterior border of the heart to the abdomen.

5. Turn the heart over and notice the large *sternal artery* which runs downwards and forwards from the abdominal artery, just as it leaves the heart.

s. Remove the ovary and the liver from one side of the body, tracing the course of the hepatic artery, and notice near the anterior edge of the floor of the body cavity, the great external mandibular muscle (Fig. 100, *s*).

t. *The Respiratory Organs*. Cut through the roof of the branchial chamber of one side, and raising it up, notice that its upper inner edge is continuous with the skeleton of the flancs, while its lower external edge is continuous

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with the reflected lower edge of the carapace. Dissect the membrane away and expose the gills.

1. Each gill is pyramidal in shape, and is made up of a series of leaflets, which are bound together by a tubular stem, the vessel which carries venous blood to the gills.

2. At the bottom of the gill-chamber notice a long, flat, sword-shaped flap (m) fringed with hairs, — the flabellum of the first maxilliped. Separate the mouth-parts, and seizing the base of the first maxilliped with a pair of forceps, move the appendage, and notice that, as it moves, the flabellum moves up and down over the outer surfaces of the gills.

3. Pass a bristle into the opening above the base of the second maxilla, and notice that it passes into the branchial chamber outside the bases of the gills.

4. Underneath the external mandibular muscle notice a smooth, transparent elevated, chitinous ridge, the exhalent channel, through which the water passes away from the branchial chamber. Notice that the bristle passes through this channel.

5. Turn the tips of the gills back, in order to expose their inner surfaces, and notice that the lamellæ are united to each other by an internal hollow stem, the vessel which carries the aerated blood down to the bases of the gills, and then up to the pericardium.

6. Notice that there is an internal branchial chamber between the gills and the flancs. Pass a bristle into the opening at the base of the third maxilliped, and notice that its inner end projects into the internal branchial chamber.

7. At the bottom of this chamber notice a flabellum like that in the outer chamber. Move the third maxilliped, and notice that the inner flabellum moves at the same time.

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In the anterior portion of the inner chamber notice a much smaller flabellum which is carried by the second maxilliped.

8. Disarticulate and remove the three maxillipeds with their flabella, in succession, and notice again the form and position of the flabellum of each of them.

9. Notice that while each gill is free from those on each side of it, and from the outer and inner walls of the branchial chamber, it is enclosed by a tough chitinous

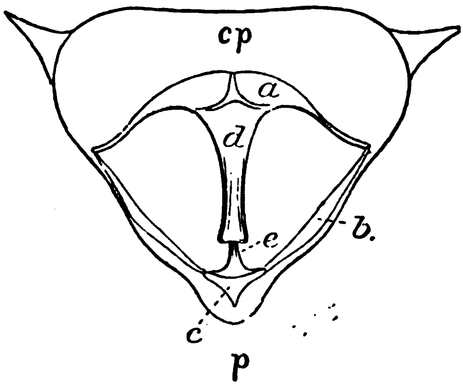

FIG. 101.

FIG. 101.—Upper surface of the "cardiac" pouch of the stomach of Callinectes hastatus; with the muscles removed to show the *gastric mill.* (Drawn from nature by W. K. Brooks.)

(For explanation of letters, see Fig. 102.)

cuticle, which is continuous, at the base of the gill, with the calcified shell. When the shell is moulted the chitinous covering of the gills is also pulled off, as part of the cast shell.

10. Place a living specimen in water, and notice the current which is drawn through the slit at the base of

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the third maxilliped, into the inner branchial chamber and out from the outer branchial chamber to the opening above the second maxilla where the water is bailed out by the scaphognathite, and swept away from the body in a current which flows forwards, between, and under the maxillipeds.

11. Carefully cut away the carapace of a living specimen in order to expose the gills and heart. Notice the play of the flabella in the branchial chamber, and the

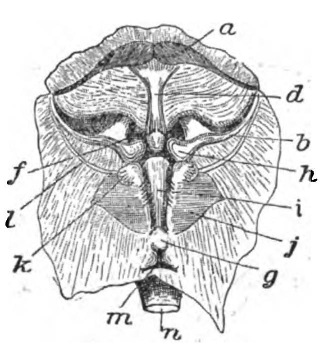

FIG. 102.

FIG. 102.—Inside view of posterior portion of "cardiac" pouch of the stomach of Callinectes hastatus. (Drawn from nature by W. K. Brooks.)

Explanation of the reference letters in Figs. 101 and 102 :—

a. Pterocardiac ossicle. *b.* Zygocardiac ossicle. *c.* Pyloric ossicle. *d.* Urocardiac ossicle. *e.* Prepyloric ossicle. *f.* Opening into pyloric pouch. *g.* Valvular fold over the opening of the œsophagus. *h.* Zygocardiac tooth. *i.* Bottom of stomach. *j.* Inferior accessory ossicles. *k.* Accessory cardiac tooth. *l.* Superior accessory ossicles. *m.* Opening of œsophagus. *n.* Œsophagus. *p.* Posterior end of stomach. *c p.* Cardiac pouch.

rhythmical beating of the heart. Make a small opening through the pericardium, and introducing a few drops of some colored fluid, such as finely-powdered carmine in water, notice the manner in which it is drawn through the

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ostia into the heart, to be forced out again through the arteries at each contraction.

u. The *Digestive Organs.*

These are the *mouth appendages*, the *œsophagus*, the *stomach*, the *pyloric coeca*, the *liver*, the *intestine*, and the *intestinal coecum.*

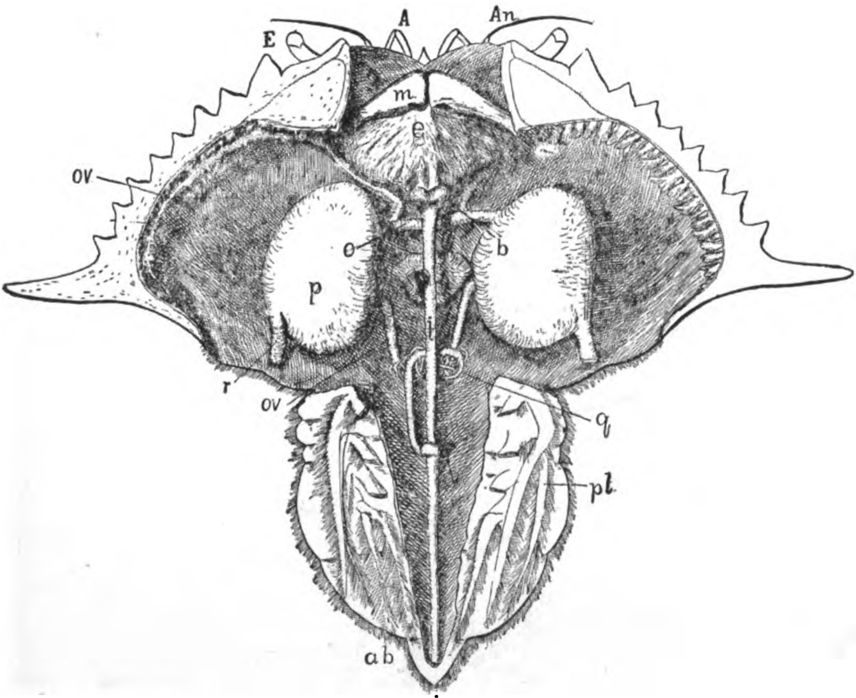

Fig. 103.

Fig. 103. — Female specimen of Callinectes hastatus; opened from below to show the reproductive organs. (Drawn from nature by J. E. Armstrong.)

A. Antennules. *An.* Antennæ. *E.* Eyes. *a b.* Abdomen. *b.* Pyloric pouch of stomach. *e.* Cardiac pouch of stomach. *j.* Intestine. *m.* Mandible. *o.* Crossbar of ovary. *o v.* Ovary. *p.* Seminal receptacle. *q.* Intestinal coecum. *p l.* Abdominal appendages. *r.* Oviduct.

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1. The *stomach* consists of two portions or chambers: the large transparent membraneous "*cardiac*" *pouch* (Figs. 103 and 104, *e*) which fills the anterior median portion of the body, and which, as already noticed, is exposed when the carapace is removed, and a posterior, much smaller "*pyloric*" *pouch* (Figs. 103 and 104, *b*). Raise up the posterior border of the "cardiac" pouch and under it, at a

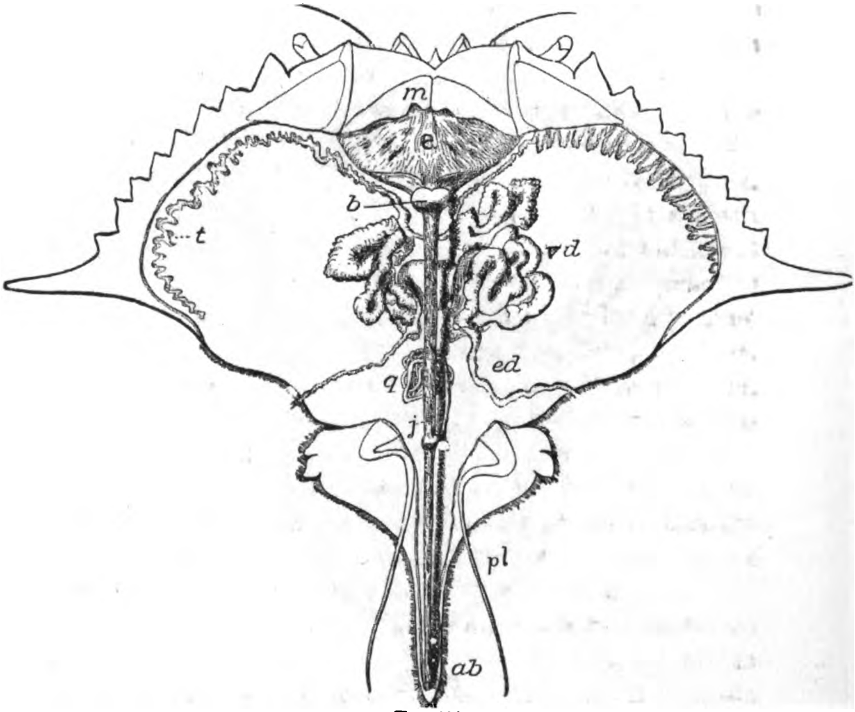

FIG. 104.

FIG. 104. — Male specimen of Callinectes hastatus; opened from below to show the reproductive organs. (Drawn from nature by J. E. Armstrong.)

_t._ Testis. _v d._ Vas deferens. _e d._ Ejaculatory duct. Other letters as in Fig. 103.

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somewhat lower level, notice the small pyloric pouch, with firm, thick, greatly folded walls.

2. Turn the "cardiac" pouch to one side, and notice the short, wide œsophagus which runs up from the mandibles to open on its lower floor. Notice that a great part of the "cardiac" pouch is anterior to the œsophagus. Pass a bristle between the mandibles, through the mouth and œsophagus, and notice that it projects into the cardiac pouch.

3. The *liver* is a very large organ, which not only runs out along the edge of the carapace, as shown at *i* in Fig. 100, but also runs under the stomach and the heart, and fills the greater part of the body cavity. Notice that it is divided up into lobules, and carefully examining one of these lobules, notice that it consists of great numbers of small *hepatic tubules*, which are so loosely bound together that they readily separate from each other, or "fray out." Notice that the tubules converge on each side of the body to form an hepatic duct, which opens into the pyloric chamber of the stomach.

4. The "*pyloric*" *coeca*. These are a pair of long, slender, white, convoluted tubes, which are twined between the ovaries, the liver, and the mandibular muscles, on each side of the pyloric pouch, into which they open.

5. The *intestine* (Figs. 103 and 104 *i*) is a long, straight, transparent, dark-colored tube, which runs along the middle line of the body below the heart and posterior branches of the ovary, from the pyloric pouch to the *anus*, which is on the ventral or upper surface of the tip of the abdomen.

6. The intestinal coecum is a long coiled tube (Figs. 100, 103, and 104, *q*) which opens into the intestine in the second abdominal somite. It consists of two parts: a convoluted portion which forms a compact ball (Fig.

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100, *q*) back of the heart, and usually on the right, sometimes on the left side of the intestine, and a straighter portion which runs back from the coiled portion to open into the intestine.

7. The *gastric mill.* Notice once more the anterior and posterior gastric muscles which run from the cardiac pouch to the carapace; clean them off, and notice, in the wall of the cardiac pouch a pair of stiff, white, calcareous rods (Fig. 101, *a*), the *pterocardiac ossicles*, which meet each other on the median line, while their slender, outer ends run outwards and downwards onto the sides of the stomach, where they join the *cardiac latero-superior ossicles* or zygocardiacs (Fig. 101, *b*). These incline backwards, upwards, and inwards, and their hinder ends join a small transverse bar, the *pyloric ossicle* (Fig. 101, *c*) which lies near the posterior end of the stomach. The pterocardiac and pyloric ossicles are joined to each other by a pair of *median gastric muscles* (Fig. 100, *c*); and, removing these, note that they do not lie on the surface of the stomach, but that they roof over a deep, conical depression produced by an infolding of the stomach-wall between the pterocardiac and pyloric ossicles. From the point of union of the two pterocardiac ossicles, a stout bar, the *urocardiac ossicle* (Fig. 101, *d*) runs downwards along the anterior edge of this pit, while a much smaller *prepyloric ossicle* (Fig. 101, *e*) runs from the middle of the pyloric ossicle (*c*) along the posterior face of the pit, to join the lower end of the urocardiac ossicle.

Turn the stomach to one side, and, cutting the œsophagus and intestine, remove it from the body, and notice in a side view the large, thin-walled cardiac pouch and the much smaller, thick-walled pyloric pouch. Carefully clear away the layer of muscles which forms the greater part of

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the stomach-wall, and notice that it is lined by a tough, thin, transparent, chitinous coat, which is thickened and calcified at certain points to form the ossicles of the *gastric mill.* Open the cardiac pouch in front, to expose the opening into the pyloric pouch and the ossicles which surround it, and spreading it out notice again : —

(i.) The *pterocardiac ossicles* (Fig. 102, *a*).

(ii.) The *urocardiac ossicle* (Fig. 102, *d*), projecting downwards and backwards, in front of the opening (*f*) into the pyloric pouch, and ending below in a dense urocardiac tooth.

(iii.) On each side of and a little anterior to this tooth, notice the zygocardiac teeth (Fig. 102, *h*), two dense, thick, dark-colored prominences, which are carried upon the inner sides of the *zygocardiac ossicles* (*b*), and which have their inner surfaces marked by ridges and furrows, something like the molar teeth of a rodent.

(iv.) On the floor of the stomach notice the opening (*g*) of the œsophagus, guarded by valvular folds of the wall of the stomach, and posterior to the mouth, a groove or channel (*i*) which runs backwards to the pyloric orifice (*f*), where it ends in an *inferior cardiac tooth*, which lies a little behind and below the tip of the urocardiac tooth.

(v.) On each side of this gutter notice a large, triangular plate (*j*), the inferior *accessory cardiac ossicle*, the inner edge of which forms the wall of the gutter, and is marked by a number of parallel ridges.

(vi.) Above this on each side a long slender *superior accessory cardiac ossicle* (*l*), which runs downwards and inwards from the anterior end of the zygocardiac ossicle, to terminate in a soft, hand-like tooth (*k*), with a number of slender, finger-like processes. This is the accessory cardiac tooth.

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(vii.) Study in another specimen the way in which these ossicles are moved upon each other by the gastric muscles, and make drawings of the outer and inner surfaces of the stomach.

v. The *antennary glands.* After removing the stomach, notice on each side of and a little anterior to the œsophagus, and in front of the mandible, the flat, coiled, greenish-white antennary gland.

w. The *female reproductive organs.* These vary in size according to the season. They consist of the *ovary*, two *seminal receptacles*, and the oviducts.

1. The *ovary* consists of two lateral portions (Fig. 103, *ov*, *ov*), which run from the outer angles of the carapace along its anterior border, and then backwards, inwards, and downwards, along the stomach, and then upwards and backwards on each side and a little above the intestine as far as and sometimes into the first abdominal somite, and a median portion or cross-bar (Fig. 103, *o*) which joins the two lateral halves just above the pyloric pouch of the stomach.

2. The *seminal receptacles*, (Fig. 103, *p*) are two pouches which vary greatly in size according to the season. They are on the inner surface of the sternal plastron, and each communicates, on its upper surface, with one of the lateral divisions of the ovary.

3. The *oviducts* are very short tubes, which run from these pouches to the female reproductive orifices, in the sternum of the somite which carries the third pair of pereiopods.

4. Dissect out and draw the female reproductive organs.

5. If a female is found carrying eggs, notice the manner in which they are fastened to the hairs of the abdominal appendages and covered by the abdomen.

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x. The *reproductive organs of the male crab.*

The *testis* (Fig. 104, *t*) is very similar to the ovary, and consists of two lateral portions and a cross-bar. Each lateral portion gives rise to a very long, greatly convoluted, transparent white tube, the *vas deferens* (Fig. 104, *vd*), which passes into a straighter portion, the ejaculatory duct (*ed*), opening on the coxopodite of the fifth pereiopod. Carefully examine the base of this joint, and notice that the duct is prolonged, outside it, as a soft white tube, which runs into the base of the first pleopod, into which it opens.

y. The *Nervous System.*

Another specimen should, if possible, be used for studying the nervous system. It should be opened from above by cutting away the carapace, and, if a fresh specimen is used, it should be placed in seventy-five per cent alcohol as soon as it is opened, and the dissection should be carried on under the alcohol.

Turn the cardiac pouch to one side, and notice on the lower surface of the anterior portion two white small *gastric ganglia*, each of which is joined to a large nerve, which runs forwards to the floor of the anterior edge of the carapace, near which it enters the outer end of one of the *cerebral ganglia.* These are a pair of pear-shaped ganglia, united to each other on the middle line of the body, and giving off from their narrow ends nerves to the eyes, the antennæ, the antennules, the gastric ganglia, and the lining of the carapace.

They also give rise to a pair of *œsophageal commissures*, or small nerves which run backwards, one on each side of the œsophagus, into the cavity of the sternal plastron. Just behind the œsophagus these commissures are united to each other by a transverse commissure; and at the outer

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ends of this, on the longitudinal commissures, are a pair of small ganglionic enlargements, which give rise to a pair of small nerves to the muscles of the mandibles, and also to a small pair which run up onto the stomach, to the gastric ganglia.

Trace the longitudinal commissures backwards into the sternal plastron, where they join the *thoracic ganglia*, a white ring, perforated in the centre, and giving off, on each side, nerves to the maxillæ, the maxillipeds, and the pereiopods. The sternal artery passes through the ring. Carefully examine the ring with a lens, and notice that it is made up of a number of small ganglia fused together, but still showing traces of their separate outlines. Notice a small nerve which runs backwards from the ring into the abdomen.

z. The *Auditory Organs*.

Cut away the external or lower surface of the large basal joint of the antennule, and notice that it is almost entirely filled by the auditory sac, an irregular, greatly folded vesicle, the wall of which is chitinous, but somewhat flexible. Notice that the wall of the sac is united to the inner surface of the upper side of the shell which covers the basal joint of the antennule. The sac has no external opening, but a line, fringed with hairs, on the outer surface of the joint, marks the line along which it is joined to the shell. Cut the sac out, and opening, notice that it does not contain any grains of sand or other solid bodies. Examine its inner surface, under water, with a hand-lens, or a low power of the microscope. Notice a row of long, slender *auditory hairs*, which project from the wall into the cavity of the sac. There are also great numbers of much smaller hairs scattered irregularly over the inner surface of the sac.

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XXI. THE METAMORPHOSIS OF A CRAB.

(*Callinectes hastatus.*)

THE material gathered at the surface of the ocean with the dip-net, as described in Section VII., will usually be found to contain specimens of the various stages in the metamorphosis of crab-larvæ. They are all sufficiently alike to be used in verifying the following description; so it is not necessary to obtain the larvæ of Callinectes.

I. The *Zoea Stage.* If the water which has been collected with a dip-net on a calm summer evening be placed in a glass beaker and held before a light, numbers of crab-zoeas will usually be found. They are very active, and they show a slight tendency to collect at the surface on the side nearest the light, although they may be found swimming in all parts of the beaker. They may be recognized by comparison with Fig. 105, which is a highly magnified side view of the zoea of Callinectes about twelve hours after its escape from the egg.

Catch several zoeas with a dipping-tube, and placing them in a watch-crystal with a small quantity of sea-water, examine them with a power of from fifty to one hundred diameters, and notice: —

a. The very large compound eyes (Figs. 105 and 106, *E*).

b. The shell, or carapace (Figs. 105 and 106, *c*), which covers up the anterior portion of the body.

c. The long, movable, jointed abdomen (*a*) which projects from underneath the posterior edge of the carapace, and ends in a large, forked telson.

d. Between the eyes the carapace is prolonged downwards to form a long, slender, pointed *rostrum* (Figs. 105

and 106, *r*), the length of which varies greatly in different species.

e. Near the posterior edge of the middle of the dorsal surface the carapace is prolonged to form a slender, pointed *dorsal spine* (Figs. 105 and 106, *d*), the length of which also varies greatly in different species.

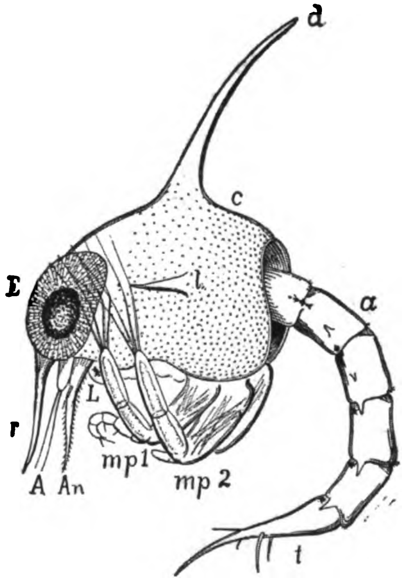

FIG. 105.

FIG. 105. — Zoea of Callinectes, one day after hatching, seen from the left side, magnified about eighty diameters. (Drawn by W. K. Brooks from a sketch from nature by E. B. Wilson.)

A. Antennule. *An*. Antenna. *a*. Abdomen. *c*. Carapace. *d*. Dorsal spine. *E*. Eye. *L*. Labrum. *l*. Lateral spine. *mp*¹. First maxilliped. *mp*². Second maxilliped. *r*. Rostrum. *t*. Telson.

f. In Callinectes the sides of the carapace give rise to a pair of shorter lateral spines (Figs. 105 and 106, *b*), which are absent in the zoeas of many crabs.

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g. Notice the transparent, pulsating *heart*, at the base of the dorsal spine, and the *intestine*, running from underneath the carapace out to the tip of the abdomen, to open at the *anus*, between the forks of the telson. Notice that the intestine dilates a little near the anus, to form an en-

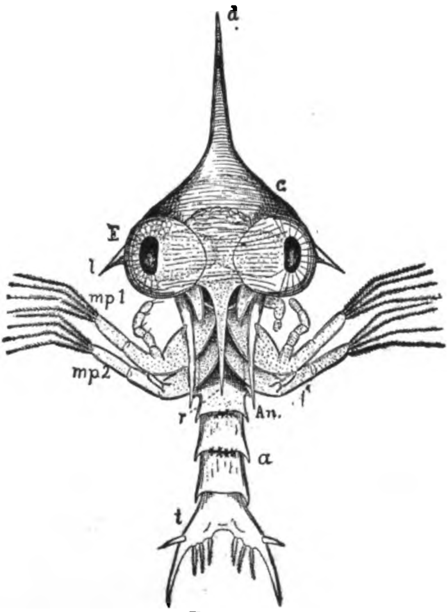

FIG. 106.

FIG. 106. — Anterior view of the same zoea. (Drawn by W. K. Brooks from a sketch by E. B. Wilson.)

The reference letters are the same as those of Fig. 105.

larged *rectum*, which is attached to the integument by a number of small, radiating muscular fibres, and is rhythmically contractile like the heart. The enlarged stomach and liver may be obscurely seen through the side of the carapace.

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h. Notice the two pairs of swimming feet (Figs. 105 and 106, *mp*[1], *mp*[2]), which project beyond the lower edge of the carapace, and end in long swimming hairs. They are the first and second pairs of maxillipeds, which are organs of locomotion in the zoea, but mouth-parts in the adult crab.

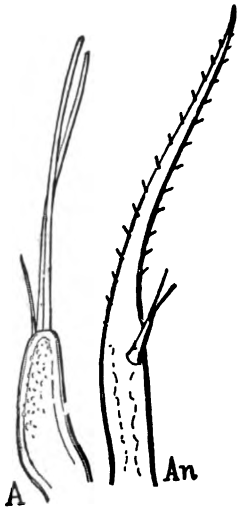

FIG. 107.

i. Notice the antennules (Fig. 105, *A*), and the antennæ (*An*) projecting downwards behind the rostrum. They vary greatly in size in different zoeas, and may be much longer or much shorter than they are in Callinectes.

j. A large rounded *labrum* (Fig. 105, *L*) lies on the middle line of the ventral surface, and between it and the bases of the maxillipeds are the *mandibles*, and two pairs of *maxillæ*.

FIG. 107. — Antennule and antenna of the zoea shown in Fig. 105. (Drawn by W. K. Brooks from a sketch by E. B. Wilson.) *A.* Antennule. *An.* Antenna.

k. Make a sketch of the zoea showing these points.

l. Place a zoea on a glass slide in a drop of sea-water, and laying a piece of paper near it to support the cover-glass, gently cover it, and examine it with a higher power, noticing: —

1. The *antennules* (Fig. 107, *A*). Each consists of a short swollen basal joint, which carries two long sensory hairs, and, in Callinectes, a third much shorter hair. Notice that the two long hairs do not taper, but are uniformly thick from base to tip.

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2. The *antennæ* (Fig. 107, *An*). These consist of two portions: a *spine*, which in Callinectes is about as long as the rostrum, and is fringed with short hairs; and a shorter movable *exopodite*, or *scale*, which springs from near the base of the spine, and ends in two slender, tapering hairs. The scale corresponds to the scale at the base of the antenna of a lobster or crayfish, and the flagellum of the antenna of the adult crab is absent in the newly hatched zoea.

3. The *labrum* (Fig. 108, *L*). This is a rounded, projecting, hood-like organ, which is usually marked by a conspicuous dendritic pigment spot. Its posterior free edge is fringed with short hairs.

4. The *mandibles* (Fig. 108, *M*). These are usually marked by pigment spots, and their cutting edges have two or three hook-like points or "teeth." The mandibles are not exactly alike, the left differing from the right a little. The palpus carried by the mandible of the adult is entirely absent in the zoea.

5. The *first maxilla* (Fig. 108, Mx^1) consists of three portions: a basipodite (*b*), a coxopodite (*cx*), and an endopodite (*en*).

The basipodite and coxopodite together make up the long protopodite or body of the maxilla, and their inner edges are fringed with stout plumose hairs. The endopodite is more slender, two-jointed, and it ends with a few long slender plumose hairs.

6. The *second maxilla* (Fig. 108, Mx^2) consists of a protopodite (*p*), an endopodite (*en*), and an exopodite or scaphognathite (*sc*). The protopodite is made up of a small coxopodite (*cx*) and a much larger basipodite (*b*). The free inner ends of these joints are notched or bilobed, and carry long, slender, plumose hairs. The tip of the

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single-jointed endopodite is also bilobed, and carries four long plumose hairs. The scaphognathite is a flattened plate, with a long plumose hair at its distal end, a much stouter one at its proximal end, and three smaller ones

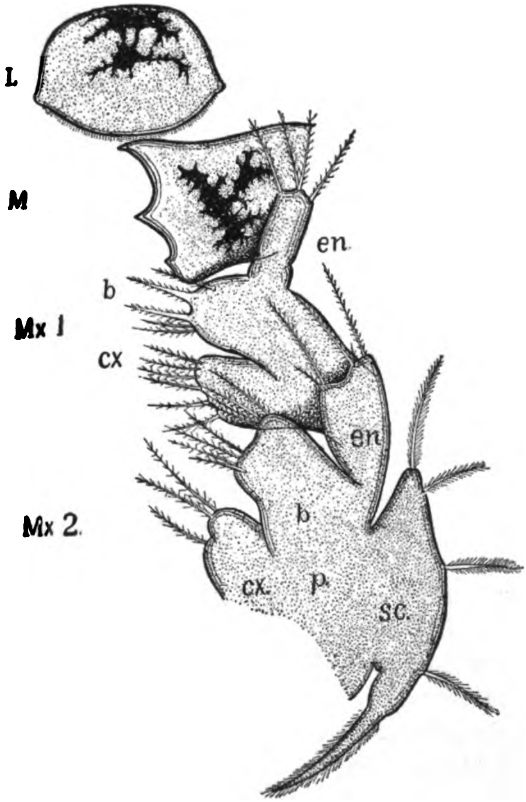

FIG. 108.

FIG. 108.—Mouth-parts of the zoea shown in Fig. 105, seen from below. (Drawn by W. K. Brooks from sketches by E. B. Wilson.)

L. Labrum. *M.* Mandible. *Mx*¹. First maxilla. *Mx*². Second maxilla. *b.* Basipodite. *cx.* Coxopodite. *en.* Endopodite. *p.* Protopodite. *sc.* Exopodite or scaphognathite.

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along its outer edge. These hairs are much more finely plumose than those on the other mouth-parts.

7. The *first maxilliped* (Fig. 109, Mp^1). This consists of a large muscular protopodite, which carries an exopodite (*ex*) and an endopodite (*en*). The exopodite is

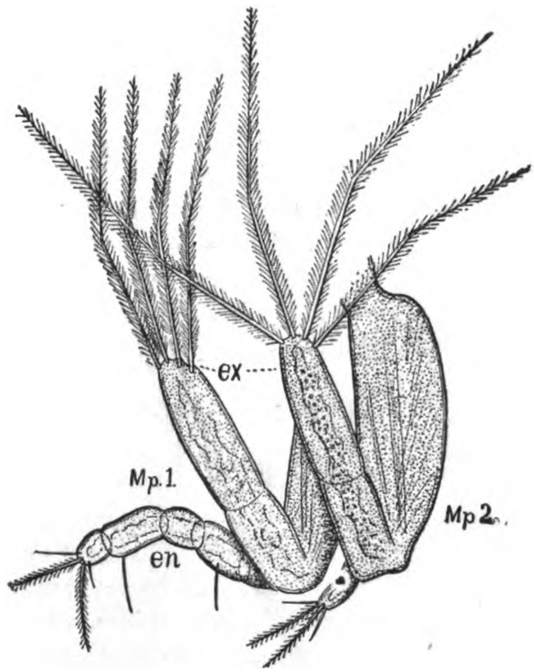

FIG. 109.

FIG. 109.—Maxillipeds of the same zoea. (Drawn by W. K. Brooks from a sketch by E. B. Wilson.)

Mp^1. First Maxilliped. Mp^2. Second maxilliped. *ex.* Exopodite. *en.* Endopodite.

two-jointed, flattened, and is usually bent upwards against the side of the carapace. It ends in four long, two-jointed, plumose swimming-hairs. The endopodite is about as

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long as the exopodite, cylindrical, and five-jointed. It ends with two long plumose hairs and two shorter simple hairs.

8. The *second maxilliped* (Fig. 109, Mp^2). This is much like the first maxilliped, but its endopodite is rudimentary.

These are all the appendages which are present in the newly-hatched zoea of Callinectes, but in the older zoea of this species, and in the newly-hatched zoeas of many other species a nearly vertical series of bud-like protuberances will be seen underneath the edge of the carapace, between the base of the second maxilliped and the first segment of the abdomen. These buds are the rudimentary *third maxillipeds* and the *pereiopods*.

9. Make careful drawings of the appendages of the zoea, and compare them with the corresponding appendages of the adult.

10. The *abdomen* (Figs. 105 and 106, *a*). This consists of five free segments, the sixth being fused with the telson. The telson is deeply forked, the anus is in the notch of the fork, and on each side of it there are a number of plumose hairs: three hairs in the newly-hatched zoea of Callinectes, but none in some other species. The pointed prong of the telson carries two movable hairs or spines, which are not plumose.

11. Make a sketch of the telson.

m. The *Embryonic Zoea*. A few minutes after hatching, the zoea of Callinectes has the form above described; but if a crab zoea be taken immediately after leaving the egg, it will be found to be enclosed in a delicate, transparent, embryonic skin, which is very quickly stripped off as soon as the larva begins to swim. Place a female crab with eggs in an aquarium, and, keeping her until the eggs

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hatch, place some of the larvæ under the microscope, and examining them very carefully with a high power, notice the larval skin, which conforms very closely to the outline of the body of the zoea except upon the antennules, the antennæ, and the telson. The embryonic antennule is very much larger and longer than that of the zoea, and it carries a long, hairy branch, and a second much shorter branch. The antenna of the embryonic skin is also very much larger than that of the zoea. It divides near its base into two branches, one of which is short and blunt, while the other ends in three long, plumose, swimming-hairs. The telson of the embryonic skin is also very much larger than that of the zoea, and is a slightly-forked fan-like organ, with seven pairs of large, transparent, swimming-hairs, five of them plumose.

n. The *Older Zoea.*

The zoea sheds its skin a number of times, the bud-like rudiments of the third maxillipeds and pereiopods grow a little, and the portion of the body which carries them becomes obscurely divided into segments, the abdominal feet or pleopods make their appearance as pairs of buds on the ventral surface of the abdominal segments, and the endopodite or flagellum appears upon the antenna, and the palp on the mandible.

For a number of moults the change of the larva is gradual; but after a time it sheds its skin and becomes suddenly converted into a larva which is quite different from the zoea, and which is known as a *Megalops.*

II. The *Megalops Stage* (Fig. 110). The megalops larvæ may easily be reared from zoeas, or they may be obtained by surface-collecting. They are able to swim actively, but they frequently cling to the sides of the glass beaker, where they may be recognized by their resem-

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blance to small crabs. Catch two or three specimens with a dipping-tube, and place them in a tumbler of sea-water, where they may be kept alive for examination.

a. Place one of them in a watch-crystal, in enough sea-water to cover it, and, examining it with a low power,

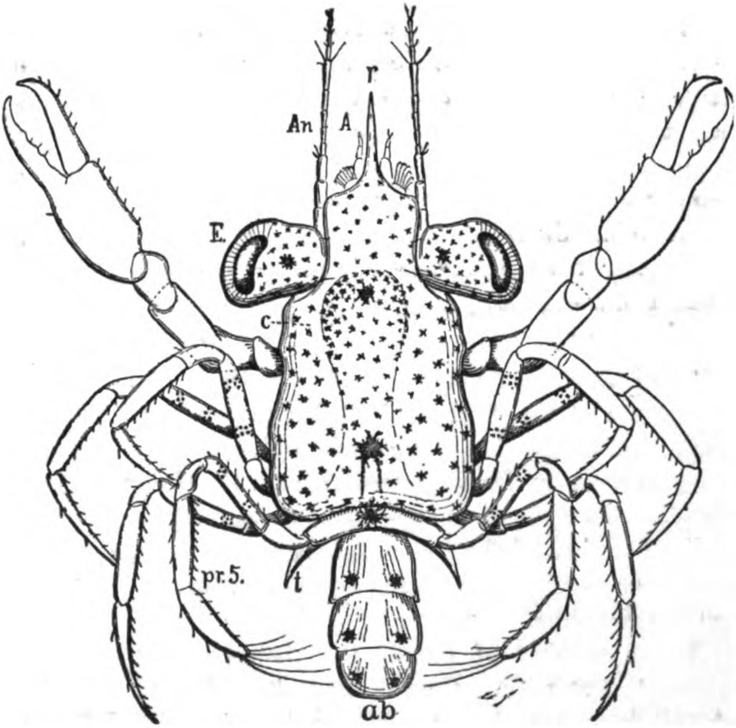

Fig. 110.

Fig. 110. — Megalops of Callinectes or of a closely-allied crab, magnified about eighty diameters. (Drawn from nature by W. K. Brooks.)

A. Antennule. *An*. Antenna. *ab*. Abdomen. *c*. Carapace. *E*. Eye. *pr*. 5, Fifth pereiopod. *r*. Rostrum. *t*. Fifth thoracic somite.

notice that it differs from the zoea and resembles the full-grown crab in the following respects: —

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1. The carapace (Fig. 110, *c*) has no lateral spines, and either no dorsal spine or a very small one.

2. The eyes (Fig. 110, *E*) are at the ends of very movable stalks.

3. The five pairs of pereiopods are fully developed, and are very similar to those of the adult.

4. The gills have made their appearance, above the bases of the pereiopods, under the lateral margin of the carapace, but these margins are still free, as they are in the zoea.

5. The maxillipeds are no longer organs of locomotion, and there are three pairs.

6. While the larva is still able to swim, it also moves over the bottom by walking upon the tip of the pereiopods, with a crab-like gait, very similar to that of the adult.

b. It differs from the adult in the following conspicuous features: —

1. There is a long, pointed rostrum (Fig. 110, *r*) at the anterior end of the carapace.

2. The eyes (*E*) are not covered by the carapace, and they are not upon the anterior edge, but upon the sides of a median frontal region.

3. Both antennules and antennæ project from beneath the edge of the carapace, and the flagella of the antenna (*An*) are very long.

4. In Callinectes, and in many other species, the fifth pair of pereiopods (*pr*. 5) are bent upwards and backwards above the dorsal surface of the carapace.

5. The segment (*t*) which carries them is movable.

6. There is a long, movable, six-jointed abdomen (*ab*), which carries five or six pairs of biramous swimming-feet, and ends in a small, rounded telson. While the animal is swimming the telson is stretched out behind the carapace,

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but while crawling it may be bent forwards under the ventral surface of the fore-body, as in the adult.

c. Make a drawing of the megalops larva, showing as many of these points as possible.

d. Examine the appendages more carefully, dissecting them out with needles, and notice : —

1. The basal joint of the *antennule* (Fig. 110, *A*) is swollen, and the otocyst may be seen through the transparent integument. Its opening on the upper surface is fringed by a few long hairs, which project beyond the edge of the carapace.

2. The flagellum of the *antenna* (Fig. 110, *An*) is comparatively very much longer than it is in the adult, and single. The basal joints of the antenna are not very much larger or longer than the terminal joints, and it is not doubled back under the carapace.

FIG. 111.

FIG. 111. — First maxilla of the Megalops of Portunus. (From Claus, *Untersuchen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems.* Taf. xiii.)

1. Coxopodite. *2.* Basipodite. *en.* Endopodite.

3. The *mandible* is very similar to that of the adult, and carries a jointed palp.

4. The *first maxilla* (Fig. 111) is very similar to that of the adult, but the hairs upon its basal joints are less numerous, and comparatively very much longer.

5. Ths *second maxillæ* (Fig. 112) also have larger and less numerous hairs, and the scaphognathite (*sc*) is fringed with hairs around its entire edge.

6. The exopodite (*ex*) of the *first maxilliped* (Fig. 113) is quite like that of the zoea, and carries four long hairs,

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and lacks the many-jointed tip which is found in the adult. The endopodite (*en*) is free from the exopodite, and has only a few hairs, but in other respects it is similar to that of the adult, and very different from that of the zoea. The appendage carries a long flabellum (*f*), which projects into the gill-chamber, and is like that of the adult, but with only a few long hairs. The basal joints of the appendage (*1* and *2*) are very different from those of the zoea, and are very similar to those of the adult.

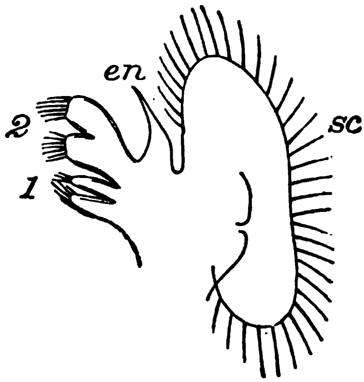

FIG. 112.

FIG. 112.—Second maxilla of the same larva. (From Claus.)
1. Coxopodite. *2.* Basipodite. *en.* Endopodite. *sc.* Scaphognathite.

7. The exopodite of the *second maxilliped* (Fig. 114, *ex*) is like that of the zoea, but in other respects the appendage is like that of the adult.

8. The *third maxilliped* (Fig. 115) is fully developed, and much like that of the adult, except that the basal joints of the endopodite are not flattened to form a *mouth-cover*, or gnathostegite, and the gill is carried upon the basal joint of the limb, instead of upon the episternum.

9. The pereiopods (Fig. 116) are essentially like those of the adult, except that their gills are upon their basal joints.

10. The abdominal appendages. These are carried by all or by the last five abdominal somites, and each consists

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of a basal portion and two hairy paddles; but the endopodites of opposite sides join each other on the middle line.

e. Observe that the abdomen and abdominal appendages of the megalops larva are much more like those of the adult female than those of the adult male.

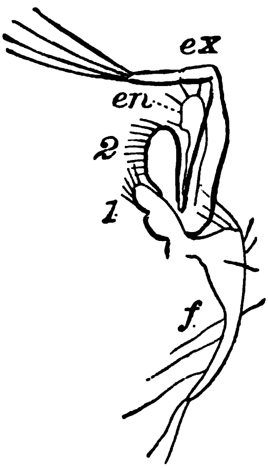

FIG. 113.

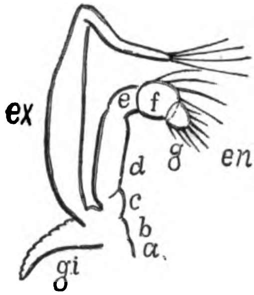

FIG. 114.

FIG. 113. — First maxilla of the same larva. (From Claus.)
1. Coxopodite. *2.* Basipodite. *en.* Endopodite. *ex.* Exopodite. *f.* Flabellum.

FIG. 113. — Second maxilliped of the same larva. (From Claus.)
a. Coxopodite. *b.* Basipodite. *c.* Ischiopodite. *d.* Meropodite. *e.* Carpopodite. *f.* Propodite. *g.* Dactylopodite. *en.* Endopodite. *ex.* Exopodite. *gi.* Gill.

f. Make drawings of the appendages of the megalops larva.

g. Carefully compare the various parts of the megalops larva with those of the adult crab, and with those of a lobster or crayfish, and notice that the larva resembles the lobster in the following points of difference from the adult: —

1. There is a rostrum.

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2. The lateral margins of the carapace are free from the body.

3. The antennæ are long.

4. The third maxillipeds are not flattened.

5. The gills are on the basal joints of the limbs.

6. There is a free, movable, jointed abdomen, used in locomotion.

7. There are numerous biramous swimming abdominal appendages.

8. There is a free telson.

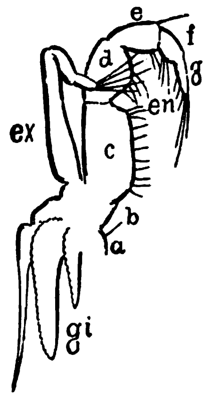

FIG. 115.

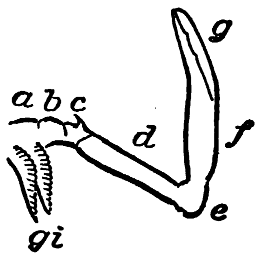

FIG. 116.

FIG. 115. — Third maxilliped of the same larva. (After Claus.) Letters as in Fig. 114.

FIG. 116. — Pereiopod of the same larva. (After Claus.) Letters as in Fig. 114.

h. Keep a larva in confinement until it changes into the young crab (Fig. 117).

i. The *auditory organ.* The integument of the megalops larva or of the very young crab is sufficiently transparent to render the examination of the hearing organ possibl .

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without dissection, and the young stages are therefore more favorable than the adult crab for studying the organ.

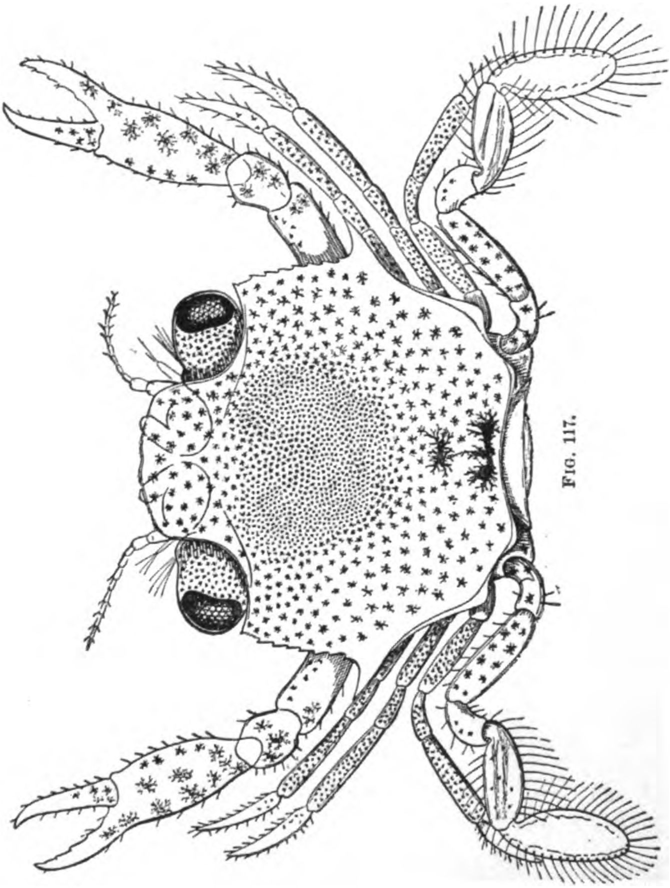

FIG. 117. — Young crab which moulted from the Megalops shown in Fig. 110. (Drawn from nature by W. K. Brooks.)

Place a megalops larva in a watch-crystal, in a few drops of water, and covering it with a thin glass cover, to keep

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it quiet, examine the basal joints of the antennules with the highest magnifying power that can be used (from fifty to one hundred diameters). Notice the thin-walled, transparent vesicle, the otocyst, which nearly fills the enlarged basal joint of the antennule. On the upper surface of the antennule notice the transverse slit through which the otocyst opens to the exterior. Notice the row of hooked hairs which project over this slit, as a sort of thatch. In the cavity of the otocyst a number of small grains of sand. A row of long, slender, sensory hairs, which project from the wall of the otocyst into its cavity, on the side nearest the median line of the body. On the posterior or basal side an irregular cluster of shorter hairs.

An examination of the hearing organ of the adult crab, and of the lobster or crayfish, will show that the megalops larva differs from the adult and resembles the lobster, in having the otocyst open to the exterior. The grains of sand also are present in the otocysts of the lobster, but absent in that of the adult crab.

XXII.—THE ANATOMY AND METAMORPHOSIS OF CYCLOPS.

Small Copepods are usually abundant in both fresh and salt water, and there is never any difficulty in obtaining them. As Cyclops is one of the most common and widely diffused fresh-water genera it has been selected for description, but there should be no difficulty in studying other forms, for although the generic differences are very considerable, they are not of such a character as to confuse the student. In order to obtain a supply of specimens of Cyclops, carefully examine the sides of an aquarium in which water plants have been growing, and search for

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very minute, active white animals, about a twenty-fifth of an inch in length. When one of these white specks comes to rest upon the side of the glass, pass a dipping-tube down to it, and removing the finger from the top, allow it to be drawn into the tube. Transfer it to a watch-glass, and, examining it with a low magnifying power, ascertain whether it resembles Fig. 118, either with or without the egg bunches (*n*); if so, it is a Copepod. The females of the fresh-water species are larger and very much more abundant than the males, and as they are therefore the most easily obtained, this account has been written with especial reference to the female, except when the contrary is stated.

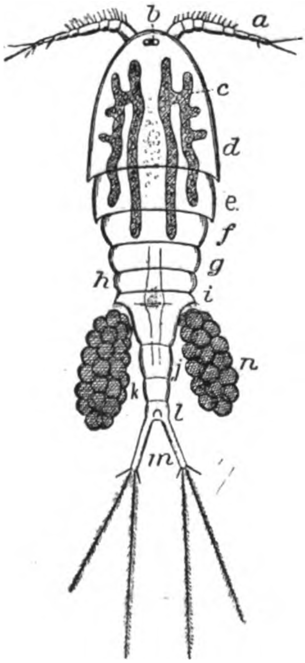

FIG. 118.

FIG. 118. — Dorsal view of female specimen of Cyclops canthocarpoides, with ovisacs highly magnified. (From Claus, *Freilebenden Copepoden.*)

a. First antennæ. *b*. Ocellus. *c*. Oviduct. *d*. Carapace. *e*, *f*, *g*, *h*. The four free thoracic somites. *i*, *j*, *k*, *l*. The abdominal somites. *n*. Ovisacs.

A number of females should be placed in a watch-crystal with only enough water to cover them, and killed by adding a small quantity of ether to the water. One or more individuals will then probably be found to present a good view of the dorsal surface for microscopic examination.

I. In the dorsal view notice that the body is divided into two regions of nearly equal length; an anterior

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larger, pear-shaped, segmented *cephalothorax*, and a narrow segmented *abdomen*, which is forked posteriorly and ends in two bunches of long hairs, which make up a little more than half the total length of the abdomen.

a. The *cephalothorax.* This is made up of an anterior unsegmented *carapace*, which is followed by a number of free thoracic somites.

1. The *carapace* (Fig. 118, *d*) is broad and a little longer than wide, and forms about a third of the entire length of the animal. Its anterior margin is rounded at the sides, but the even curve is a little broken on the anterior median line, which is occupied by a short rounded rostrum.

(i.) Upon the base of the rostrum, in the median line of the body, note the single dark brown *eye-spot (b).* A higher power shows that this is formed by the fusion of a pair of eyes, and the two lenses may be seen upon the sides of the spot.

(ii.) Projecting from below the sides of the rostrum are the large, many-jointed *first antennæ (a)*, which bend backwards along the margins of the carapace, and carry a number of scattered hairs upon tneir anterior edges.

(iii.) Beside and below these are the shorter jointed *second antennæ.*

2. Posterior to the carapace the dorsal surface of the cephalothorax is formed by the movable terge of the four free thoracic somites (*e*, *f*, *g*, *h*). These are of about equal length, but they gradually decrease in width from before backward; the first being nearly as wide as the carapace, and the fourth only about half as wide.

b. Back of the last thoracic somite is the narrow, slightly tapering *abdomen*, divided into four apparent segments.

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1. The first of these (*i*) is longer than it is wide, and its manner of development, as well as a comparison of the female abdomen with that of the male, shows that it is formed by the union of two somites.

The ovisacs (*n*) are attached to the sides of this segment, and the apertures of the oviducts indicate the line along which the two originally separate somites have become united.

2. The three following abdominal somites (*j*, *k*, *l*) are narrow, and the anal orifice may be seen near the centre of the dorsal surface of the last, which carries a pair of divergent segmented styles (*m*), each of which carries four plumose setae.

c. Notice the free setose ends of the thoracic appendages projecting beyond the edges of the free thoracic somites.

d. Make a sketch of the dorsal surface, showing all these points.

II. In order to get a satisfactory side or ventral view the animal may be placed upon a glass slide with a small drop of water, and then moved into the desired position with a needle. A small piece of paper should be placed near the specimen to support the cover-glass, which will be necessary for the satisfactory study of this aspect. In a side or ventral view note: —

a. The *shell-glands;* a pair of convoluted, transparent tubes, one on each side near the middle of the ventral margin of the carapace.

b. The *mouth* is upon the median ventral line near the anterior end, and is bounded anteriorly by a projecting *labrum*. Its posterior margin is formed by a bilobed ridge, the metastoma, which can be satisfactorily made out only in a ventral view.

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c. The appendages.

1. The large jointed first antennæ have been already noticed. They are the principal locomotor organs, and are seen, in a side view, to be the first or most anterior pair of jointed appendages.

2. Next posterior to these are the second antennæ, which have already been noticed.

3. On the sides of the mouth are the stout, blunt, dark-colored *mandibles* (Fig. 119).

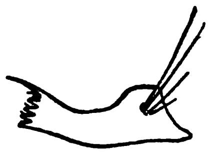

FIG. 119.

FIG. 119.—Mandible of Cyclops canthocarpoides. (From Claus.)

FIG. 120.

4. Behind these are the incurved setose *first maxillæ* (Fig. 120), which, like the mandibles, have cutting edges.

FIG. 120.—First maxilla of Cyclops canthocarpoides. (From Claus.)

5. The *second maxillæ* (Fig. 121) are jointed, and consist of two portions, the *exopodite* (*ex.*), which is much the larger, and, in a side view, is anterior to the smaller-jointed endopodite (*en*). These parts are mounted upon a protopodite, which, as well as the exopodite and endopodite, carries plumose setae. The proximal portion of the exopodite carries three distal joints, which are placed side by side, and may be folded down upon the proximal portion, like fingers bent down into the palm of the hand.

6. Considerable space intervenes between the mouth-parts and the thoracic appendages, of which there are five pairs, the four anterior pairs being about equal in size, and the fifth pair rudimentary. The first pair of limbs

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lies under the posterior margin of the carapace, and the following pairs are the appendages of the four free thoracic somites. Each of these appendages, the last excepted, consists of a two-jointed protopodite, which carries an exopodite and an endopodite, each of which is three-jointed. All the segments of the limb carry long delicate plumose setae upon their posterior or inner margins, and stout, serrated, movable spines upon their anterior or outer margins. The fifth thoracic appendage consists of a basal joint and two spines, which appear to represent the exopodite and endopodite.

FIG. 121.

FIG. 121.—Second maxilla of Cyclops canthocarpoides. (From Claus.)

d. Near the middle of the first abdominal segment are the large oval openings of the oviducts, one on each side of the body. The margin of the opening is thickened and is prolonged posteriorly into a projecting spine, which probably serves to support the ovisacs.

e. Make a drawing of the side view, showing these points.

III. The *Digestive Tract.* This is a nearly straight tube which runs along the middle line from the mouth to the anus. Its anterior end is large and its thick walls contain large brown hepatic cells. The posterior portion is smaller and more transparent, and exhibits active contractions. In the anterior portion of the abdomen there is usually an enlargement filled with partially-digested food, but it may be absent, and its position is not constant.

IV. The *reproductive organs* of the female consist of a single *ovary*, two *oviducts*, and a *spermatheca*.

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a. The ovary is in the middle line of the dorsal surface of the carapace. Its appearance varies somewhat at different times, and when nearly empty of eggs it is transparent and almost invisible.

b. On each side of it is a long, branched oviduct (Fig. 118, *c*) which is very dark and granular at its anterior end when distended with eggs, while the posterior portion is more transparent and difficult to detect. The eggs are small and transparent when they leave the ovary, but they become larger and opaque in the oviducts.

The oviducts pass backwards to open on the sides of the first abdominal segment, at the point *a* of Fig. 122, and the opening is covered by a little lid which is fringed with hairs, and serves for the attachment of the ovisacs.

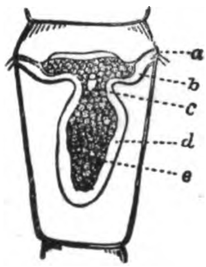

FIG. 122.

FIG. 122. — Highly magnified diagrammatic view of the ventral surface of the first abdominal somite of a mature female specimen of Cyclops brevicaudatus. (From Graber. Taf. xxvi. Fig. 11.)

a. Setose plate of integument which covers the external opening of the oviduct. *b.* Spermatic duct, through which the semen (*e*) passes from the spermatheca (*d*) to the oviduct. *c.* Vulva, or orifice to which the spermatophore is attached, and through which the spermatozoa pass into the the spermatheca. *d.* Spermatheca. *e.* Spermatic fluid.

c. Under the integument of the ventral surface of the first abdominal segment, notice a transparent oval sac, the *spermatheca* (Fig. 122, *d*). It opens to the exterior by a median ventral aperture, the *vulva* (Fig. 122, *c*), through which the seminal fluid of the male passes into the sac.

On each side of its anterior end a small tube, the *spermatic duct* (Fig. 122, *b*) runs outwards and upwards to

open into the oviduct, close to its termination. The eggs are fertilized while passing this opening on their way out of the oviduct.

V. The *Examination of the Male.*

The males are very rarely found, but they may occasionally be captured while copulating with the females. They are very much smaller than the females, and they differ from them in the following respects: —

a. The first antennæ are more stout than those of the female, and near the tip of each there is a hinge-joint, which allows the terminal portion to fold down onto the basal portion, like a knife-blade shutting into its handle. These antennæ are the *clasping* organs, by which the male clings to the abdomen of the female.

b. The male abdomen is made up of five somites, of which the first and second correspond to the first segment of the female abdomen.

c. The *reproductive organs* of the male consist of a single median testis, and two long winding *vasa deferentia.*

1. The *testis* (Fig. 123, *t*) is a small compact transparent body on the median line, above the digestive tract, under the posterior edge of the carapace. It is divided, at its anterior end, by a notch, into two divergent branches, each of which is continued to form, —

2. The *vas deferens:* a long folded tube (Fig. 123, *vd*) divided into three regions.

(i.) The first division (123, *vd. 1*) is a delicate transparent tube, with a thick wall, and a very small central cavity. It runs downwards and backwards to the second or third thoracic somite, and then bends forwards again nearly to the anterior edge of the testis. These two bends are bound up in a single sheath. The cavity of this portion of the vas deferens, which is simply a duct to

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convey the seminal fluid from the testes to the second chamber, is usually empty, since the seminal fluid passes through it quite rapidly to the second portions.

(ii.) The second region or spermatophore-forming portion (*vd. 2*) is not abruptly separated from the first division. It reaches from the carapace to the first abdominal somite, and its cavity is usually distended by the spermatozoa which have passed to it from the testes through the first division. They are here stored up, and, as they accumulate, are packed together to form a complex *spermatophore*, which will be more fully described later.

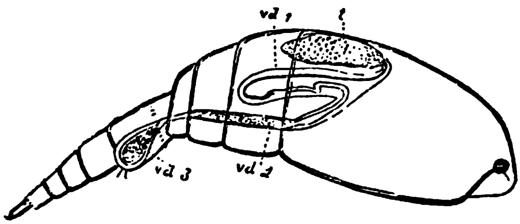

FIG. 123.

FIG. 123.—Outline of the right side of the body of a male specimen of Cyclops tenuicornis, without the appendages, to show the reproductive organs. (From Graber, *Beiträge zur Kenntniss der Generations-organe der freilebenden Copepoden.* Zeit. f. Wiss. Zool. xxxiii. Taf. xxv., Fig. 1.)

t. Testis. *vd. 1.* The first or proximal region of the vas deferens. *vd. 2.* The second or spermatophore-forming region. *vd. 3.* The third region, or receptacle of the spermatophore.

(iii.) The third region (Fig. 123, *vd. 3*) is a short, enlarged pouch, the *receptacle* of the *spermatophore*, separated by an abrupt constriction from the second region, and opening externally on the posterior edge of the first abdominal somite, under a small lid or flap (Fig. 124, *h*) which carries three stout hairs projecting backwards from its free edge. After a spermatophore has been formed in

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the second region it passes into this receptacle, where it remains until it is transferred to the body of the female.

3. The *spermatophore*. The seminal receptacle usually contains a spermatophore; but as this is gradually completed in this cavity, perfectly mature spermatophores are the exception rather than the rule. The arrangement of the parts of the spermatophore varies somewhat in different species, but the following four structures are always present: the *sheath*, the *discharging bodies*, the *spermatozoa*, and the *cement*.

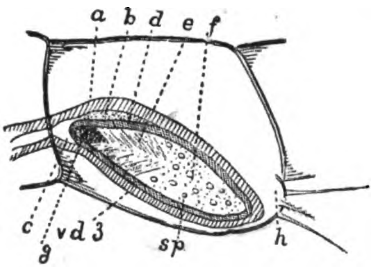

FIG. 124.

FIG. 124. — Diagrammatic view of the left side of the first abdominal somite of a male specimen of Cyclops tenuicornis, more highly magnified, to show the ripe spermatophore in the terminal region of the vas deferens. (After Graber, Taf. xxv., Fig. 3). *vd*. The enlarged terminal portion of spermatophore receptacle of the left vas deferens. *sp*. Spermatophore. *h*. Lid-like plate which covers the external genital orifice at the lower edge of the posterior end of the first abdominal somite. *a*. Wall of vas deferens. *b*. A mass of cement inside the cavity of the duct. *c*. Cavity of the duct. *d*. Spermatophore sac. *e*. Spermatozoa, filling the anterior half of spermatophore. *f*. Discharging bodies filling the posterior end. *g*. Cement body and anterior end.

(i.) The sheath, or *spermatophore sac* (Fig. 124, *d*) is a delicate, transparent, oval pouch, which is secreted around the spermatozoa in the second chamber of the vas deferens. The sheath is not quite complete, since its inner or anterior end is open.

(ii.) The *discharging bodies* (Fig. 124, *f*) form a transparent mass, which, in some species, fills the posterior closed end of the sac, as shown in the figure, but in other

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species it forms a layer just inside the sac, over the whole spermatophore.

If a male with a ripe spermatophore be gently pressed under a cover-glass, the wall of the sac may be ruptured so that the contents may escape as shown in Fig. 125, and the discharging bodies (*c*) may then be seen to be small, transparent, highly refractive spherules, which soon absorb water, swell, and disappear. When the ripe spermatophore is transferred from the reproductive organs of the male to the body of the female, as described further on, the contact with the water causes these spherules to swell, and drive the other contents of the spermatophore out of the sac into the seminal receptacle of the female.

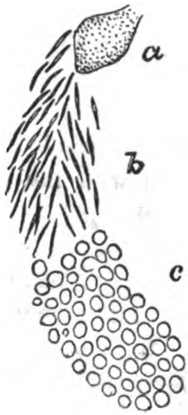

Fig. 125.

Fig. 125. — Contents of a ripe spermatophore of Cyclops tenuicornis, which has been ruptured by pressure. (From Graber, Taf. xxv., Fig. 5.)
***a*. Cement. *b*. Spermatozoa. *c*. Discharging bodies.**

(iii.) The greater part of the cavity of the sac is filled by the spermatozoa (Figs. 124, *c*; 125, *h*; 126). When forced out by pressure they will be seen to consist of an oval sheath with an inner spiral thread. The spermatozoa of Cyclops are motionless.

(iv.) The anterior end of the sac is usually occupied by an adhesive plug, the cement (Figs. 124, *g*; 125, *a*); but in some species the cement occupies the central axis instead of the anterior end.

4. If possible notice the manner in which the spermatophore is transferred to the vulva of the female, where it is

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fastened by the cement, until the discharging bodies drive the spermatozoa into the seminal receptacle. Males and females may occasionally be found while copulating; and if they are examined with a lens, the male may be seen to clasp the thoracic limbs or abdomen of the female with his jointed antennæ, and then, bending up his body, deposit a spermatophore upon the external median aperture of the seminal receptacle. This spermatophore adheres to the body of the female, and the spermatozoa are absorbed into the gland, and each time that eggs are laid a sufficient number pass up through the ducts already noticed to fertilize them. It is probable that one impregnation serves for the whole life of the female. At any rate, one connection with the male serves to fertilize several broods of eggs.

FIG. 126.

FIG. 126. — Spermatozoa of Cyclops tenuicornis, highly magnified. (From Graber, Taf. xxv., Fig. 2.)

Place two or three egg-bearing females in a large watch-crystal full of water; cover this with another crystal, or with a glass tumbler, and set it aside until the eggs hatch. Then carefully examine the water around the edges of the crystal for the very minute and active young. Having found a specimen, catch it with a dipping-tube, and transferring it to a glass slide, examine it with a power of two hundred and fifty to three hundred diameters.

VI. The *Nauplius Stage.* The newly-hatched larva of a Copepod is known as Nauplius. It has an oval body (Fig. 127), and three pairs of jointed locomotor appendages, and presents the following points for examination.

a. The middle of the ventral surface of the body is occupied by a large oval labrum (Fig. 127, *L*), through which the opening of the mouth may be seen.

b. Around the mouth the three pairs of appendages are arranged.

1. The first pair (*A*), which become the first antennæ of the adult, are the smallest, and consist of three setose joints.

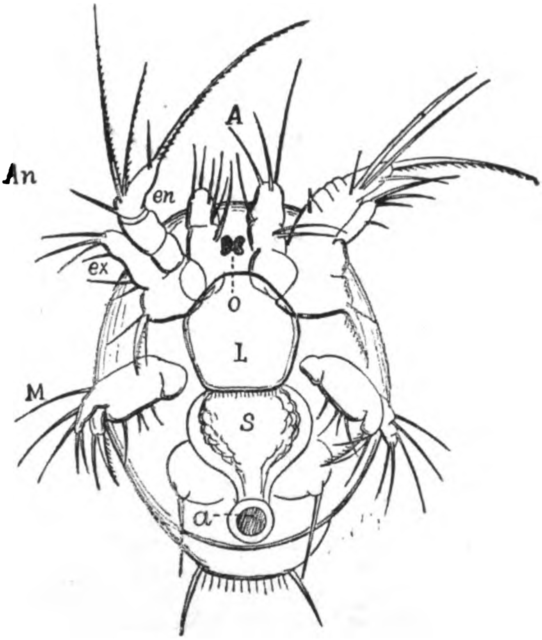

FIG. 127.

FIG. 127.—Nauplius of Canthocamptus Staphylinus, magnified five hundred and seventy-five diameters. (From Hoek, *Ent. der Entomostraken.* Niederl. Arch. IV.)

A. First antennæ. *An.* Second antennæ. *a.* Anus. *en.* Endopodite. *ex.* Exopodite. *L.* Labrum. *M.* Mandible. *o.* Ocellus. *s.* Stomach.

2. The second pair (*An*), which become the second antennæ of the adult, are much larger, and are the main organs of locomotion. Each consists of a large setose

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protopodite, which carries a jointed exopodite (*ex*) and endopodite (*en*). All the joints carry movable setae, and the terminal joints also bear long plumose hairs.

3. The third pair of appendages (*M*) are much like the second, and become the mandibles of the adult.

c. The dorsal surface is almost entirely covered by the oval carapace, near the anterior margin of which is the black double eye-speck (*o*).

d. Posterior to the carapace is the last abdominal segment, which carries the anus (*a*), and a pair of terminal setae.

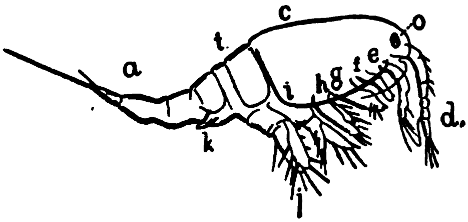

FIG. 128.

FIG. 128. — Young Cyclops, with two pairs of fully-developed thoracic limbs, and a rudimentary third pair. (From Claus, in Bronn's *Klassen u. Ordnungen des Thierreichs.* Arthropoda Taf. xiii., Fig. 6.)

a. Abdomen. *c*. Carapace. *d*. First antenna. *e*. Second antenna. *f*. Mandible. *g*. First maxilla. *h*. Second maxilla. *i*. First thoracic appendage. *j*. Second thoracic appendage. *k*. Rudimentary third thoracic appendage. *t*. Thoracic somites. *o*. Ocellus.

e. The digestive tract consists of: —

(i.) A short œsophagus, which runs upward and forward from the lower surface of the labrum.

(ii.) The dark-colored stomach (*s*).

(iii.) The pear-shaped thick-walled intestine.

f. Upon each side of the stomach is a transparent circular tube, the shell-gland, which does not seem to be furnished with an external opening.

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g. After two or three moults the posterior end of the body lengthens to form the long hind-body of the adult, while the rounded anterior portion becomes the carapace of the adult. The mandibles develop cutting blades upon their basal joints, and the two pairs of maxillæ make their appearance as small buds on the ventral surface of the body.

h. After one or two more moults, the second antenna becomes uniramous, as shown in Fig. 128, *e*. The blade (*f*) of the mandible becomes fully developed, and the two terminal branches of the nauplius mandible disappear. The two pairs of maxillæ (*g*, *h*) assume their adult form, and the thoracic appendages (*i*, *j*, *k*) and the free somites of the thorax and abdomen appear, in succession, from in front backwards. The larva changes gradually, through a number of moults, until the adult form is reached.

XXIII.—THE HARD PARTS OF THE GRASSHOPPER.

(*Acridium Americanum.*)

The following description was written from the above species, which should if possible be procured for laboratory work, as its large size makes it an especially good type for elementary work. Any other grasshopper may, however, be used, or even a cricket, or a cockroach. Fresh specimens, or those which have been preserved in alcohol, will answer for examination. If the alcoholic specimens are stiff and brittle they may be softened by placing them in warm water for a few hours.

Examine a fresh or a preserved specimen, and notice the

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long, narrow, laterally compressed body, which is divided into three well-marked regions.

1. The *head*, which is flattened from before backwards, and elongated vertically. It carries the eye, the antennæ, and the mouth-parts, and is movably joined, by a short neck, to the second region of the body.

2. The *thorax*, which, with the head, constitutes the anterior half of the body. On its lower surface it carries the three pairs of legs, which increase in size from before backwards, the third pair being much the largest. The posterior portion of the dorsal surface of the thorax carries the two pairs of wings.

3. The *abdomen*, which is a little longer than the head and thorax together, is made up of a series of movable segments without appendages.

4. The *wings*. The anterior pair of wings, which are known as the *tegmina*, or *wing covers*, are about as long as the body, beyond the posterior end of which they project. They are narrow, and the anterior and posterior margins are seen, when the wing is extended, to be nearly parallel. When folded upon the body their outer faces are vertical, with the anterior margin below, and the posterior or *internal* edges in contact along the back, the left slightly overlapping the right.

a. With a pair of forceps seize the lower edge of the wing-cover, at about the middle, and gently expand it by pulling it downwards and outwards until it is at right angles to the body. Notice that the surface which was exposed in the folded wing-cover is now uppermost, and the edge which was below when folded is now the anterior edge or *costal margin*.

b. Remove one of the wing-covers for examination. It is a thin, transparent, rather stiff plate of chitin, irregu-

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larly marked with dark-brown pigment spots. It is strengthened by a network of chitinous tubes, the "*veins*"; of which there are five on each wing, diverging from the proximal end of the wing, and giving rise to smaller veins. These in turn divide into much smaller *veinlets*, which inosculate with each other and divide the surface of the wing into small irregular polygonal areas or "*cells*."

(i.) The vein nearest the anterior or *costal* margin of the wing is the *costal vein*. It is undivided, and may be traced for a little more than half the length of the wing.

(ii.) The second very much larger vein is the *sub-costal*. It gives rise to several large branches, the subdivisions of which form the framework of the greater part of the wing.

(iii.) The third or *median* is much smaller, and soon divides into two branches of nearly equal size.

(iv.) The remaining pair, which are known as the *sub-median* and *internal*, run close to and nearly parallel with each other near the *internal* or posterior margin of the wing.

c. The wing is divided by the veins into three areas: —

(i.) The *costal* area forms the anterior edge of the wing, and is bounded posteriorly by the costal vein.

(ii.) The *median* area is much the largest, and lies between the sub-costal and sub-median veins.

(iii.) The *internal* area is the free margin posterior to the internal vein.

d. Make a sketch of the wing-cover, showing the above points.

e. The second pair of wings are about equal to the first in length, and when the animal is at rest are folded up under the latter. On the side from which the wing-cover has been removed seize the dark-colored marginal vein of

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the second wing with a pair of forceps and extend it with a gentle pull outwards and forwards. It is then seen to be a thin parchment-like membrane, with a stiff anterior edge, which is nearly straight, while the rounded outer and posterior margins are thin and flexible. When the wing is fully extended its upper surface is convex, and its anterior margin is rendered still more rigid by being overlapped by the internal margin of the wing-cover.

The numerous radiating veins are so arranged that their elasticity causes the wing to fold upon itself like a fan as soon as its margin is released.

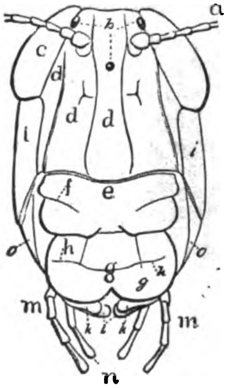

FIG. 129.

FIG. 129. — Front view of head of grasshopper (Acridium Americanum). (Drawn from nature by W. K. Brooks.)

a. Antennæ. *b.* Ocelli. *c.* Eyes. *d, d. d.* The frontal portion of the epicranium. *e.* Clypeus. *f.* Suture across the clypeus. *g, g.* Labrum. *h.* Suture across labrum. *i.* Gena. *k.* Tips of maxillæ. *l.* Tips of ligulæ. *m.* Maxillary palpus. *n.* Labial palpus. *o.* Mandibles.

5. The *Legs.* Remove and examine the large leaping-leg of the side from which the wing-cover was taken. It consists of five regions: —

a. The *coxa*, or basal division (Figs. 130, *8*, and 132, *d*, *d′*, *d″*), which is joined to the thorax.

b. A small division, the *trochanter* (Fig. 132, *e*, *e′*, *e″*), immovably joined to the distal dorsal portion of the coxa.

In this species the trochanter is quite small and imperfectly separated from the coxa. In most other insects it is more conspicuous, and it should be examined in a mantis, or in a beetle, for comparison with the grasshopper.

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c. The *femur*, a long, swollen, club-shaped segment (Figs. 130, *10*, and 132, *f*, *f'*, *f''*), which makes up nearly half the length of the limb. When the animal is at rest the femur of the third or leaping leg extends upwards and backwards, with its distal end above the dorsal surface of the body, as in Fig. 139, *Fem*.

This joint contains the powerful leaping muscles, the areas indicating the points of attachment of which are visible externally.

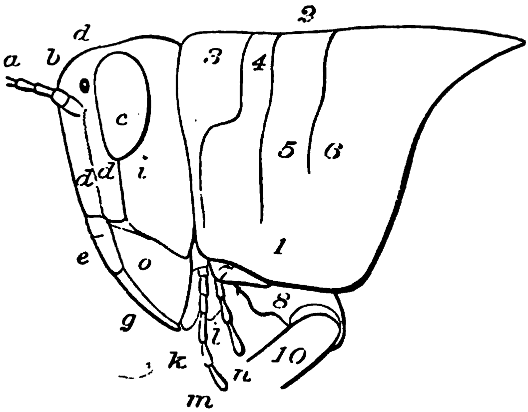

Fig. 130.

Fig. 130. — Side view of head and prothorax of grasshopper (Acridium Americanum). (Drawn from nature by W. K. Brooks.)

***a*. Antenna. *b*. Ocellus. *c*. Eye. *d*, *d*. Epicranium. *e*. Clypeus. *g*. Labrum. *i*. Gena. *k*. Maxilla. *l*. Labium. *m*. Maxillary palpus. *n*. Labial palpus. *o*. Mandible. *1*. Lateral portion of pronotum. *2*. Dorsal portion of pronotum. *3*. Prothoracic prescutum. *4*. Prothoracic scutum. *5*. Prothoracic scutellum. *6*. Prothoracic postscutellum. *7*. Prosternum. *8*. Coxa of first leg. *10*. Femur of first leg.**

In the grasshoppers of this family, the Acridii, the well-known musical sound is produced by rubbing the inner rough surface of the femur across the ridges formed by the veins of the wing-cover.

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d. The *Tibia;* about equal to the femur in length, but very slender and of uniform diameter (Fig. 139, *t*). When at rest it extends downwards and backwards, at an acute angle, from the distal end of the femur, but in the act of leaping it is thrown backwards and the limb becomes straight.

e. The *tarsus*, or foot (Fig. 139, *tr*), is made up of four movable pieces: —

(i.) The first and longest carries, upon its lower surface, three soft pads, which, by their adhesion to foreign bodies, serve as a point of resistance in leaping.

(ii.) The second joint is much shorter, and carries but one pad.

(iii.) The third is long and slender, with two curved pointed claws, the *ungues*, between which is a concave sucking disk, the fourth joint or *pulvillus*.

f. Note that the first and second pairs cf legs are much like the third, but much smaller, and meeting the body at a different angle, to fit them for crawling instead of leaping.

g. Make a sketch of the third leg, indicating the joints.

6. The *head*.

The outer or dorsal surface of the head consists of a very broad and long frontal surface which looks forward, and a much smaller and shorter dorsal occipital area.

a. The *epicranium* forms the covering of the dorsal occipital area (Fig. 130, *d'*), and then becomes narrow and runs downwards between the eyes and antennæ to about the middle of the frontal area, where it again enlarges (Fig. 129, *d*, *d*, *d*), and ends below in a prominent, straight, transverse suture. Along the middle of the occipital area there is a faint line, much more pronounced in the young than in the adult, which appears to

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indicate that the epicranium is made by the fusion, along the median line, of two originally separate pieces. Running across the narrow portion between the upper ends of the eyes is an obscure ridge which separates the occipital portion from the frontal, and may indicate the union of two originally separate segments.

b. The large, projecting, oval, highly polished compound *eyes* (Figs. 129 and 130, *c*), are situated upon the upper portion of the sides of the head. They are marked with parallel vertical bands of brown pigment; and with a lens the many thousand hexagonal facets or corneæ of the compound eye may be seen.

c. A little anterior to the upper margin of each of the compound eyes is a convex oval area, in which the integument is so thin and transparent that the white subjacent tissue may be seen. These spots are the *ocelli* (Fig. 129, *b*). A third ocellus is situated between the antennæ on the median line of the epicranium.

d. Between the eye and the narrow frontal portion of the epicranium is an oval area, the *antennary fossa*, in the centre of which the basal joint of the antenna is fastened by a flexible membrane, which admits of motion in all directions. The *antenna* itself (Figs. 129 and 130, *a*) is made up of a small basal joint and twenty-six movable rings, which gradually increase in length from the base to the tip.

e. The lower straight edge of the epicranium articulates with a wide, short plate, the *clypeus* (Figs. 129 and 130, *e*), the sides of which are deeply notched, and show traces of a division (*f*) into two plates.

f. In front of this is the movable, flap-like *labrum* (Figs. 129 and 130, *g*, *g*, *g*), the free edge of which is deeply notched upon the median line. This notch is the

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remnant of the suture formed by the union of the halves or paired appendages which the labrum represents.

g. On the side of the head notice a suture which runs from the lower anterior angle of the eye to the lower margin of the epicranium, and separates the latter from the large plate, the *gena* (Figs. 129 and 130, *i*), which forms the side of the head, and terminates below in a free pointed edge.

h. Between the lower anterior edge of the gena and the clypeus is a dark-colored area, the outer surface of the basal portion of the *mandible* (Figs. 130, *o*, and 131, *B*).

i. Make drawings of the front and side views of the head, showing all these points.

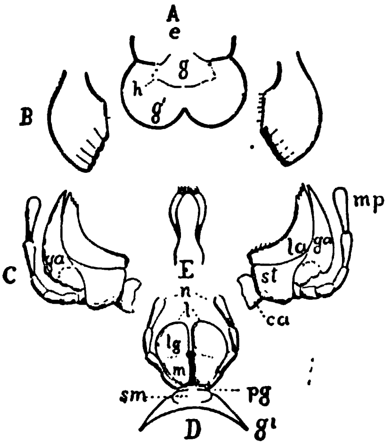

FIG. 131.

FIG. 131. — Mouth-parts of Acridium Americanum. (Drawn from nature by W. K. Brooks.) *A*. Anterior surface of the labrum. *e*. Clypeus. *g*. Labrum. *g'*. Terminal bilobed portion. *h*. Suture. *B*. Anterior surface of mandible. *C*. Posterior surface of maxilla. *ca*. Cardo. *st*. Stipes. *mp*. Maxillary palp. *la*. Lacinia. *ga*. Galea. *D*. Posterior surface of labium. *gu*. Gula. *sm*. Submentum. *pg*. Palpiger. *m*. Mentum. *lg*. Ligula. *n*. Labial palp. *E*. Metastoma.

k. Remove the head by cutting the soft integument of the neck, and raise the labrum by its free edge and cut it off. Under it note the large, black-tipped, toothed *mandibles* (Figs. 130 *o*, and 131, *B*) meeting each other upon the median line; their outer ends running

backwards, to articulate with the lower anterior edge of the gena, by a joint which allows them to move towards and away from the median line, but in no other direction.

l. On the nearly flat posterior aspect of the head notice: —

(i.) The large *occipital foramen*, by which the cavity of the head communicates with that of the neck. This foramen is bounded above by the epicranium; at the sides by the gena, and below by a crescent-shaped sternal element, the *gula* (Fig. 131, *D*, *gu*).

(ii.) Movably articulated with the lower straight edge of the gula (Fig. 131, *D*, *gu*) is the *labium* or lower lip (Fig. 131, *D*), formed by the union of a pair of appendages, which are immovably united, but exhibit, upon the median line, traces of this union. The labium consists of: —

(*a.*) A basal portion, the *mentum* (Fig. 131, *D*, *m*).

(*b.*) A pair of terminal apron-shaped pieces, convex behind and concave in front, the two halves of the *ligula* (Fig. 131, *D*, *lg*).

(*c.*) On each outer edge of the mentum is a small piece, the *palpiger* (Fig. 131, *D*, *pg*).

(*d.*) Upon this is the three-jointed labial palpus (Fig. 131, *D*, *n*).

(*e.*) Between the base of the mentum and the gula is a small immovable piece, the *submentum* (*sm*).

m. Draw the posterior aspect of the head and labium.

n. Remove the gula and the labium, and expose the posterior faces of the anterior mouth parts.

(i.) Notice, in the median line, a dark-colored, chitinous, spiny pad, the metastoma or tongue (Fig. 131, *E*), which forms the posterior boundary of the mouth. Pull it out with the forceps, and note the rows of spines which cover its anterior face.

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(ii.) Arching over the tongue and forming the anterior boundary of the mouth are the black tips of the *maxillæ*, meeting upon the median line. Each maxilla (Fig. 131, *C*) is made up of: —

(*a.*) A basal joint or *cardo* (*ca*), which is directed transversely to the long axis of the head, and articulates with the lower posterior edge of the gena.

(*b.*) The second joint, or *stipes* (*st*), runs forward at right angles to the cardo, and parallel to the long axis of the head. It is movable towards and away from the median line.

(*c.*) The *maxillary palpus* (*mp*) is carried upon the outer angle of the stipes, and is made up of three short and three long joints.

(*d.*) The *lacinia*, the toothed, black-tipped, cutting portion (*la*) of the maxilla, is carried upon the inner margin of the distal end of the stipes.

(*e.*) The *galea* (*ga*), or soft brown spoon-shaped portion of the maxilla is carried upon the outer angle of the stipes and bends around in front of the lacinia.

(iii.) Make a sketch of the maxilla, indicating all the joints.

7. The *Thorax.*

Remove the legs and wings in order to examine the structure of the thorax and abdomen. The thorax is made up of three segments, each of which carries a pair of legs. These three segments are known as the *prothorax*, *mesothorax* and *metathorax*.

a. The *prothorax.*

The sides and dorsal surface of this segment are covered by a large sunbonnet-shaped piece, the *pronotum* (Fig. 130, *2*), which bears a slight resemblance to the carapace of a crustacean, but does not, as in the latter, extend over the head.

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The dorsal portion of the pronotum is prolonged backwards along the median line, and partially overlaps the second division or mesothorax. The anterior portion of the pronotum is crossed by three grooves or sutures, which divide it into four immovably united areas.

(i.) The first of these, which forms the anterior margin of the pronotum, is known as the prothoracic *prescutum* (Fig. 130, *3*).

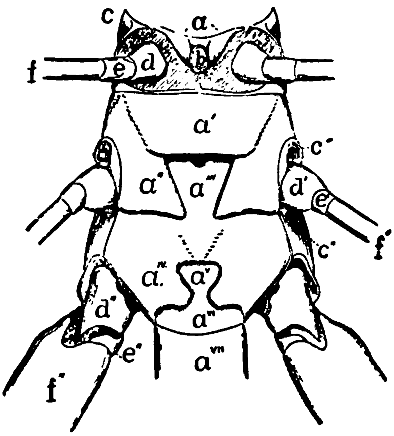

FIG. 132.

FIG. 132. — Ventral view of the thoracic region of Acridium Americanum. (Drawn from nature by W. K. Brooks.)

a. Prosternum. *a'*. Median, and *a''*. lateral portions of mesosternum. *a'''*. Median, and a^{iv}. lateral portion of metasternum. a^{v}, a^{vi}. First abdominal sternum. a^{vii}. Second abdominal sternum. *b*. Median spine of prosternum. *c*. Prothoracic episternum. *c'*. Mesothoracic episternum. *c''*. Metathoracic episternum. *d*. Prothoracic coxa. *d'*. Mesothoracic coxa. *d''*. Metathoracic coxa. *e*. Prothoracic trochanter. *e'*. Mesothoracic trochanter. *e''*. Metathoracic trochanter. *f*. Prothoracic femur. *f'*. Mesothoracic femur. *f''*. Metathoracic femur.

(ii.) The second is the prothoracic *scutum* (*4*).

(iii.) The third is the prothoracic *scutellum* (*5*).

(iv.) The last is the prothoracic *postscutellum* (*6*).

b. The ventral portion of the prothorax is formed by a slender movable sternum (Figs. 130, 7, and 132, *a*), which connects the sides of the pronotum with each other. On the median line it carries, in this species, a large hairy club-shaped spine (Figs. 132, *b*, and 139, *b*). Near the

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outer ends of the sternum are the fossæ for the attachment of the limbs.

c. Remove the first thoracic segment and make sketches of the front and side aspects.

d. The mesothorax and metathorax are much more complicated, and together with the first abdominal segment, are soldered together into a firm-walled box.

(i.) The flattened ventral surface of this box is made up of three pieces.

1. The *mesosternum*, which consists of an anterior median portion (Fig. 132, a') and two nearly rectangular posterior prolongations (a'', a'').

2. The *metasternum;* a somewhat larger plate, which consists of an anterior square tongue (a''') which fills the space between the posterior horns of the mesosternum; and a large pentagonal portion (a^{iv}), which is so placed that one of its angles points backward along the median line.

3. The first abdominal sternum (a^{v}, a^{vi}) is mortised into the posterior margin of the metasternum in nearly the same way that the latter is joined to the preceding sternum.

(ii.) In a ventral view of the thorax the lower ends of the episterna (c, c', c'') and the fossæ for the articulation of the legs are visible at the sides of the sterna.

1. Parallel with the anterior half of the mesosternum are the lower ends of the mesothoracic episterna (c').

2. Parallel with the posterior half of the mesosternum are the fossæ of the second pair of legs. The inner borders of these fossæ are not formed by the mesosternum itself, but by slender horn-like backward prolongations of the lower end of the episternum.

3. Parallel with the anterior half of the metasternum are

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the lower ends of the metathoracic episterna (c''), separating the fossæ of the second legs from those of the third, and sending prolongations backwards to form the inner margins of the latter.

(iii.) Make a drawing of the ventral view of the thorax, showing these points.

(iv.) In a side view of a thorax, from which the pronotum, wings and legs have been removed, the space above the leg fossa is occupied by four rectangular pieces, which slope obliquely upwards and forwards. The anterior margin of each of these is marked by a dark stripe or band of pigments, and the posterior margin by a light stripe.

1. The first or most anterior piece is the mesothoracic episternum. Its lower margin is prolonged downwards and backwards, and forms the anterior and lower boundary of the fossa of the second leg.

2. The second piece is the mesothoracic *epimeron*. Its lower end forms the upper and posterior margin of the leg fossa.

3. The third piece is the metathoracic episternum.

4. The fourth is the metathoracic *epimeron*.

5. Between the mesothoracic epimeron and metathoracic episternum, just above the mesothoracic leg-fossa, is a small oval aperture provided with a pair of lip-like chitinous valves. This is the respiratory aperture or spiracle of the metathoracic segment.

6. Along the upper margins of the episterna and epimera are a few small irregular pieces, to which the *wings* are articulated.

(v.) Make a drawing of the side view of the thorax, showing these points.

(vi.) The dorsal surface of the mesothorax and meta-

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thorax is formed by two nearly square areas, which occupy the space between the wings. They are soft and membraneous, and the pieces which compose them are not sharply defined.

1. The anterior border of each is formed by a narrow plate, the *prescutum* (Fig. 133, *a*).

2. Back of this is a large, convex, dark-colored, glistening surface, the *scutum* (*b*).

3. Behind the *scutum* is a membraneous piece upon the median line, the *scutellum* (*d*).

4. The posterior margin is occupied by a long, narrow, light-colored piece, the *post-scutellum* (*e*).

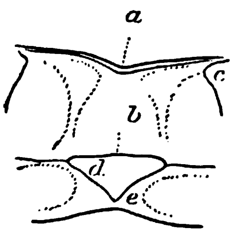

FIG. 133.

FIG. 133. — Mesonotum, or dorsal surface of Mesothorax (Acridium Americanum). (Drawn from nature by W. K. Brooks.)
a. Prescutum. *b*. Scutum. *d*. Scutellum. *e*. Postscutellum. *c*. Patagium.

5. Outside the scutellum on each side is an irregular, projecting, movable piece, the *patagium* (*c*), to which the wing is articulated.

(vii.) Make a sketch of the dorsal surface.

8. The *Abdomen*.

This is made up of a number of segments without appendages, movable upon each other, and presenting only slight differences. The typical number of abdominal segments appears to be eleven, and in both sexes of the grasshopper eleven terga are present, although only eight sterna are visible in the female and nine in the male.

a. The first abdominal segment is somewhat different from the others, and its sternal and tergal portions are widely separated. The sternal portion is immovably

united to that of the metathorax, and has been already described.

(i.) The tergum is soft, membraneous, and dark-colored like those of the thorax, and is strongly crested in the median line. Near its lower edges are a pair of large apertures closed by membrane, the auditory organs. On the anterior margin of this orifice is a much smaller opening, the first abdominal spiracle.

b. The remaining abdominal segments are composed of a narrow sternal portion and a much larger tergal portion. The two sides of the tergum meet along the back to form a ridge. Near the lower margin of each half of the tergum are a couple of longitudinal furrows, the traces of the sutures between the epimera and episterna. Near the anterior angles of the episternal regions of the second, third, fourth, fifth, sixth, seventh and eighth segments are the openings of the spiracles.

As the structure of the terminal segments of the abdomen differs considerably, according to the sex of the individual, both males and females should be studied and compared with each other. The females are more abundant than the males, and may be recognized by the presence of the strong, blunt forceps-like ovipositor which forms the posterior extremity of the body. As the male abdomen is the simplest it should be examined first.

9. The *abdomen of the male*.

a. In a ventral or a side view (Fig. 135) nine distinct movable sterna (*6** to *9**) are visible; they are nearly equal in length and similar in shape.

(i.) Posterior to the ninth sternum (*9**) the ventral surface of the body is occupied by a large spoon-shaped *sub-genital plate* (*a*), convex below and concave above. The posterior margin of this plate (Fig. 134, *a*) is deeply notched upon the median line.

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(ii.) Above this plate is a large chamber open behind and at the sides, the *genital chamber* (Fig. 135, *y*).

(iii.) On the lower floor of this chamber, and therefore on the upper surface of the sub-genital plate, is the male reproductive orifice.

b. In a dorsal view (Fig. 134) the terga are substantially alike as far as the eighth.

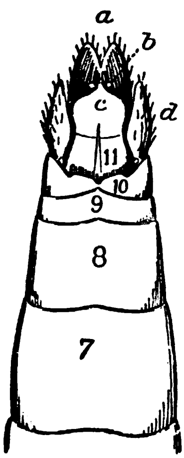

FIG. 134.

(i.) The eighth (*8*) is a little shorter than the seventh.

(ii.) The ninth (Fig. 134, *9*) is only about one-fifth as long as the eighth, and is immovably united to the tenth, a faintly marked suture separating the two.

(iii.) On the median line the tenth tergum (Fig. 134, *10*) is very narrow, but at the sides it is about as long as the ninth. The posterior margin of the tenth tergum is sharply defined.

FIG. 134.—Dorsal view of end of abdomen of male Acridium Americanum. (Drawn from nature by W. K. Brooks.)
For explanation of letters and figures see Fig. 136.

(iv.) The eleventh tergum (Fig. 134, *11*) is a movable shield-shaped plate upon the median dorsal surface. It is about as long as the eighth, and it is divided into two nearly equal portions by a faint tranverse suture. In shape it is quite different from the other terga, and its sides and posterior margin are free.

(v.) On each side of this plate the outline of the dorsal surface of the body is completed by a setose movable plate (Fig. 134, *d*), about as large as the eleventh tergum, the *cercus*. This plate projects back from the lateral margin of the tenth tergum, to which it is movably articulated.

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(vi.) Projecting beyond the end of the eleventh tergum the bilobed end of the ventral sub-genital plate (*a*) is visible.

(vii.) Raise up the end of the eleventh tergum and notice below it a pair of vertical plates (Figs. 134 and 135, *b*), one on each side of the median line, the *podical* plates. Between these plates is the *anus*, and below them the genital chamber, already noticed.

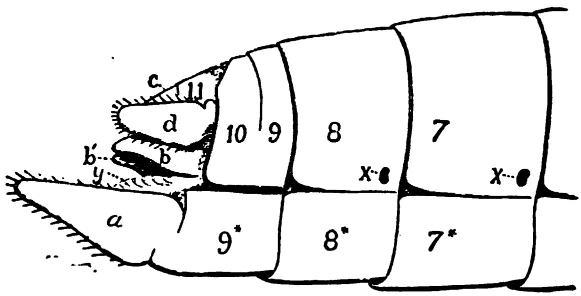

FIG. 135.

FIG. 135.—Side view of tip of abdomen of male Acridium Americanum. (Drawn from nature by W. K. Brooks.)
For explanation of letters and figures see Fig. 137.

c. In a side view (Fig. 135) notice that from the second to the eighth segment the sterna are equal in length to the corresponding terga, and the constrictions between the segments entirely surround the body.

(i.) The suture, which on the dorsal surface marks the line between the ninth and the tenth terga, does not extend down onto the sides of the body, and the lower margins of these two terga form a single plate.

(ii.) Below this plate is the ninth sternum (Fig. 135, *9**), as long as the area formed by the union of the ninth and tenth terga.

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(iii.) Running backwards from the posterior margin of the tenth tergum is the flat cercus (Fig. 135, *d*).

(iv.) Above this a portion of the eleventh tergum (Fig. 135, *11*) is visible.

(v.) Below and internal to the cercus is the podical plate (Fig. 135, *b*), triangular in a side view; and below this the large sub-genital plate (Fig. 135, *a*), which is joined to the ninth sternum.

10. The *abdomen of the female*.

a. In a ventral or side view (Fig. 137), notice:—

(i.) The first to the seventh sterna, like those of the male.

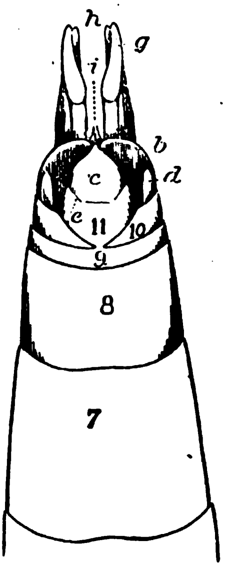

FIG. 136.

(ii.) The eighth sternum (Fig. 137, *8**) is nearly twice as long as the seventh, and forms the *sub-genital* plate. Its posterior end is pointed, curved upwards, and its extremity (Figs. 139, *11**) lies between the plates of the ovipositor.

FIG. 136.—Dorsal view of end of abdomen of female Acridium Americanum. (Drawn from nature by W. K. Brooks.)

Explanation of letters and figures for Figs. 134 and 136:—

7, 8, 9, 10, 11. Terga of the seventh to eleventh abdominal somites. *a.* Male sub-genital plate. *b.* Podical plates. *c.* Free end of eleventh tergum. *d.* Cerci. *e.* Suture. *g.* Dorsal plates of ovipositor. *h.* Ventral plates of ovipositor. *i.* Central plates of ovipositor, or "egg-guides."

b. In a dorsal view (Fig. 136), notice:—

(i.) The first ten segments, substantially like those of the male.

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(ii.) The shield-shaped eleventh tergum (Figs. 136, *11*) is shorter and wider than in the male.

(iii.) On each side of it, at a little lower level, is the triangular podical plate (Fig. 136, *b*), which is not vertical, as in the male, but is so placed that its broad surface is seen in a dorsal view.

(iv). Above, or dorsal to the podical plates, are the cerci (Fig. 136, *d*), much smaller than in the male, but attached to the posterior margin of the tenth tergum.

(v.) As in the male, the anus is between the podical plates, just below the eleventh tergum.

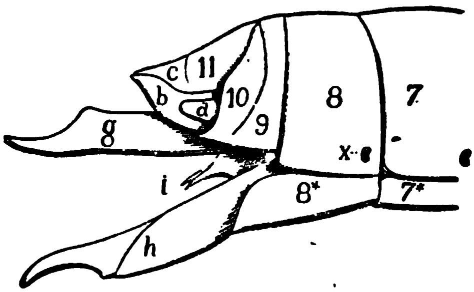

FIG. 137.

FIG. 137. — Side view of tip of female abdomen of Acridium Americanum. (Drawn from nature by W. K. Brooks.)

Explanation of letters and figures for Figs. 135 and 137.

7, 8, 9, 10, 11. Terga. *7*, 8*, 9**. Sterna. *b, b'*. Podical plates. *c*. Tip of eleventh tergum. *d*. Cerci. *a*. Sub-genital plate. *g*. Dorsal division of ovipositor. *h*. Ventral division of ovipositor. *i*. Median division of ovipositor, or "egg-guide." *x*. Spiracles. *y*. Reproductive aperture.

(vi.) The space between the podical plates above and the sub-genital plate below is filled by the ovipositor, the tip of which (Fig. 136, *g*, *h*) projects some distance beyond the eleventh tergum.

c. In a side view (Fig. 137), the terga are substantially

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like those of the male, but the small cerci (*d*) do not hide any portion of the eleventh tergum (*11*), and more of the surface of the podical plate (*b*) is visible than in the male. The large genital chamber between the podical plates above and the sub-genital plates below is entirely occupied by the ovipositor (*g*, *h*, *i*).

d. The ovipositor: this consists of six movable pieces, three on each side of the median line. These three portions are a *large superior* or *dorsal* piece (Figs. 136 and 137, *g*). Fig. 139, op^1); an equally large *inferior* or *ventral* piece (Figs. 136 and 137, *h*; Fig. 139, op^3); and a short *internal* portion (Figs. 136 and 137, *i*; Fig. 139, op^2) between the bases of the superior and inferior pieces.

(i.) In a surface view, the internal pieces are hidden by the two superior and the two inferior pieces, which are so arranged as to form a long sheath around the internal portions which form the true ovipositor. Each of the four pieces of the sheath is pointed posteriorly, and when the pieces are folded together the four tips are in contact. Running forward from the tip of each is a flattened, slightly concave surface, which in the superior pieces faces backward and upward, and in the inferior pieces backward and downward.

During oviposition the four pieces are brought together, and their tips forced into the ground. They are then separated, and their flattened surfaces force the earth away on all sides, thus making a pit, into which the internal pieces then guide the egg.

11. The *metamorphosis of the abdomen.*

Collect a number of very small, newly-hatched grasshoppers, to study the changes of the abdomen. The young, at the time they leave the egg, are essentially like the

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adult, but they have no wings, and the abdomen, in both sexes, consists of eleven distinct terga (Fig. 138, A, *6*, *7*, *8*, *9*, *10*, *11*), and ten distinct sterna (Fig. 138) *A*, 6^1, 7^1, 8^1, 9^1, 10^1). At the tip of the abdomen there are a pair of flattened podical plates (Fig. 138, *A*, *b*) and outside these a pair of long, slender cerci (Fig. 138, *A*, *d*). In the female, two long, slender processes (Fig. 138, *A*, *h*), soon make their appearance on the middle of the eighth

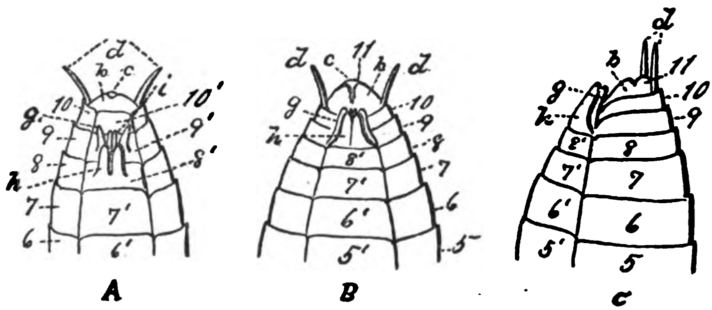

FIG. 138.

FIG. 138. — Development of ovipositor and abdominal segments of a grasshopper (Locusta virridissima). From Dewitz. "*Ban und Entwickelung des Stachels, und der Legescheide einiger Hymenopteren und der grünen Heuschrecke.*" Zeit. f. Wiss. Zool. xxv. 1875. Taf. xii. Figs. 6, and 7.

A. Ventral view of the abdominal segments of a young female grasshopper; showing the six prominences, from the eighth and ninth sterna, which are to become the parts of the ovipositor. *B*. The same a little older. *C*. Side view of *B*. *5*, *6*, *7–11*. Terga of the abdominal segments. *5'*, *6'*, *7'–10'*. Sterna of the abdominal segments. *b*. The podical plates. *c*. Tip of eleventh tergum. *d*. Cerci. *g*. Upper plates of ovipositor. *h*. Lower plates of ovipositor. *i*. Central plates of ovipositor.

sternum. These lengthen rapidly, so as to cover up the ninth and tenth sterna as shown in Fig. 138, *B* and *C*, and become the two ventral pieces of the ovipositor (Fig. 139, op^1).

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Four somewhat similar processes (Fig. 138, *A*, *g*, and *i*), appear upon the surface of the ninth sternum. They are arranged in a transverse row, and the outer ones *g*, are much larger than the inner ones, and soon lengthen to become the dorsal plates of the ovipositor (Fig. 138, *A*, and *B*, *g*; Fig. 139, *o*, *p*), while the smaller median processes (*i*), become the inner pieces or egg-guides (Fig. 139, op^2). During these changes the ninth and tenth sterna become entirely covered up and obscured, so that no traces of them are present in the adult female, and the ventral surface of the abdomen ends with the eighth sternum (Fig. 137, *8'*; Fig. 139, *11**).

The terga of the ninth, tenth, and eleventh somites (Fig. 138, *C*, *9*, *10*, *11*), persist, but their growth becomes retarded, so that they are very much shorter in the adult than those of the preceding somites, although they are of about the same length in the young.

XXIV. THE INTERNAL STRUCTURE OF THE GRASSHOPPER.

(*Acridium Americanum.*)

Pin the specimen down, under water, back uppermost, passing the pins through the wings, and along the sides of the thorax. With a pair of fine-pointed scissors cut through the integument along the dorsal surface of the abdomen, and carefully separate it from the underlying muscles, and pin it out at the sides.

a. If it has not been destroyed by the incision, notice the *dorsal vessel*, or *heart*, a delicate tube, which lies just below the integument, on the dorsal surface of the abdomen.

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b. Below the integument is a layer of small flat muscles, the abdominal muscles.

c. Cut away the integument of the thorax, and notice the large alary muscles, which entirely fill the dorsal portion of the mesothorax and metathorax. The muscles of the opposite sides of the body are sharply separated, and a thin chitinous partition runs down from the constriction between the mesothorax and metathorax, and separates the muscles of the wing-covers from those of the wings; and a similar partition from the constriction between the metathorax and first abdominal segment covers the posterior faces of the wing muscles.

d. The space between the muscles of the abdomen and the viscera is filled with a loose network of a light-colored substance, the *corpus adiposum.*

e. Running inwards from the spiracles on the sides of the thoracic and abdominal segments notice the *tracheæ,* rather tough transparent tubes, which divide into smaller branches, which pass to the various organs of the body.

(i.) Remove a small portion of the corpus adiposum; place it upon a glass slide, in a drop of water, gently cover it, and examining it with a magnifying power of about eighty diameters, notice the transparent branched tracheal tubes which ramify through its substance. Notice the spiral elastic fibre which is coiled around the wall of each tracheal tube, and which, by its elasticity, tends to keep the tube permanently open.

f. Near the dorsal surfaces of the posterior abdominal segments, surrounded by the corpus adiposum and numerous tracheæ, is the long, light-colored, reproductive gland (Fig. 139, *o*), which varies greatly in size and shape according to the age and sex of the specimen.

g. The *digestive organs.* These are quite dark in color

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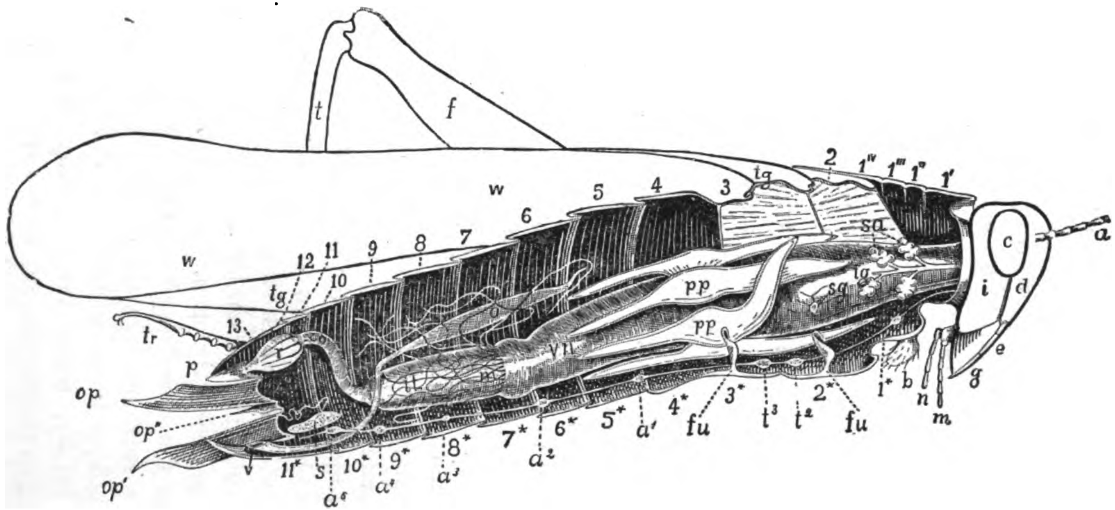
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FIG. 139.

FIG. 139. — Female specimen of Acridium Americanum, dissected to show the digestive and reproductive organs, and the ventral nerve-chain. (Drawn from nature by W. K. Brooks).

a. Antenna. a^1, a^2, a^3, a^4, a^5, the abdominal ganglia. *b.* Tooth carried by the prosternum. *c.* Compound eye. *d.* Epicranium. *e.* Clypeus. *f.* Femur. *fu.* Furcula. *g.* Labrum. *ig.* Ingluvies. *il.* Ilium. *m.* Maxillary palpus. *n.* Labial palpus. *o.* Ovary. *p.* Podical plate. *pp.* Gastric coeca. *mp.* Malpighian tubules. *r.* Rectum. *s.* Spermatheca. *sa.* Salivary glands. *sg.* Gastric ganglia. *t.* Tibia. t^2, t^3. Second and third thoracic ganglia. *tg.* Tegmen. *tr.* Tarsus. *op*, *op'*, *op''*. Ovipositor. *vn.* Ventriculus. *w.* Wing. *1'.* Prothoracic prescutum. *1''.* Prothoracic scutum. *1'''.* Prothoracic scutellum. *1^iv.* Prothoracic postscutellum. *2.* Mesothoracic tergum. *3.* Metathoracic tergum. *4–13.* The ten abdominal terga. *1*–11*.* The thoracic and abdominal sterna.

and vary slightly in structure according to the genus. The following description is strictly true only of the genus Acridium. In order to expose these organs, dissect away the corpus adiposum, the wing muscles, and the dorsal integument of the head.

They consist of: —

1. The œsophagus, a tough, dark-brown, cylindrical tube, which runs up from the mouth, and then bends at right angles and passes into the thorax.

2. In the mesothorax the œsophagus gradually enlarges to form a thick-walled pouch, the *ingluvies* or *crop* (Fig. 139, *ig*), which occupies the mesothoracic and metathoracic segments.

3. On the sides of the anterior end of the ingluvies are the delicate, white, dendritic, *salivary glands* (Fig. 129, *sa*) which communicate with two *salivary ducts*, one of which runs forward on each side of the œsophagus into the head, where they open into the cavity of the mouth.

4. In many insects the ingluvies is sharply separated by a constriction from the next region or *proventriculus*, but there is no abrupt division in Acridium, and the proven-

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triculus, which lies over the figure *3** in Fig. 139, is not sharply separated from the ingluvies.

5. Running back from the posterior end of the proventriculus to the seventh abdominal segment is a large cylindrical pouch, the *ventriculus* (Fig. 139, *vn*). Its anterior end is about as large as the posterior end of the proventriculus, and its posterior end is much smaller.

6. Surrounding the spot where these two chambers join each other are sixteen transparent, cone-shaped pouches, the *gastric coeca* (Fig. 139, *pp*), placed base to base in such a way as to form a belt of eight fusiform pouches around the digestive tract. If the tracheæ which bind them to the digestive tract are dissected away, it will be found that the pointed ends are free, eight of them running forwards on the sides of the proventriculus and eight backwards on the ventriculus.

7. Occupying the seventh, eighth and ninth abdominal segments is the *ilium* (Fig. 139, *il*), much smaller than the ventriculus, cylindrical, and abruptly constricted posteriorly, where it joins the small intestine or colon.

8. Twisted around the ilium are great numbers of small white tubes, the *malpighian tubes* (Fig. 139, *m*), which open into the ilium where it joins the ventriculus.

9. The *colon*, or small intestine (Fig. 139, *co*), is a delicate light-colored tube, which originates at the posterior end of the ilium, and bends abruptly upwards towards the dorsal surface, where it abruptly enlarges to form —

10. The *rectum* (Fig. 139, *r*), a small white sacculated pouch, which lies directly before the terga of the ninth and tenth segments.

11. The rectum opens at the *anus*, which lies between the bases of the podical plates, on the lower surface of the eleventh tergum.

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h. The *reproductive organs*.

1. The *ovary* (Fig. 139, *o*) is a long white gland, situated above the ventriculus and ilium. It is made up of two sets of tubes or *ovarioles*, which are bound together into a compact mass. When this mass is carefully examined with a lens the two sets of tubes will be seen to run upwards, forwards and towards the median line.

(i.) Near the posterior end of the ovary these tubes communicate with two delicate transparent *oviducts*, which run down around the posterior end of the ilium to the ventral surface of the body.

(ii.) Here they unite to form a single median tube, the *vagina*, which opens externally upon the upper surface of the sub-genital plate.

2. On the median line, between the internal plates of the ovipositor, there is a second much smaller external orifice, which communicates with a long slender convoluted tube, which opens into a small white pouch, the *spermatheca* (Fig. 139, *s*), which lies above the posterior end of the vagina.

i. The *nervous system*.

1. On each side of the ingluvies notice a small white stellate spot, the *gastric ganglion* (Fig. 139, *sg*), radiating from which are a number of small nerves and a larger commissure, which may be traced forwards into the head, where it joins.

2. The *supra-œsophageal ganglia*, which are situated between the eyes, in the upper surface of the œsophagus.

3. From them a pair of short commissures run down, forming a collar around the œsophagus, to the *ventral nerve chain*. This consists of commissural fibres, with the following ganglionic enlargements: —

4. A sub-œsophageal ganglion, situated in the head, and sending nerves to the mouth-parts.

5. One ganglion for each thoracic segment. In Fig. 139 the second and third of these ganglia lie above the letters t^2 and t^3, and the first is nearly over the letter b.

6. Five abdominal ganglia, one in the second, one in the fourth, one in the fifth, one in the sixth, and one in the seventh segment. In the figure these ganglia lie above the letters a^1, a^2, a^3, a^4, and a^5.

7. On each side of the nerve chain, in the second and third thoracic and the first to seventh abdominal segments, notice the *apodemata* or *furculæ* (Fig. 139, *fu*) projections from the sterna to support the nerve chain.

j. The auditory organs. In all the grasshoppers of this family, the Acridii, the organs of hearing are situated upon the sides of the first abdominal segment, and are quite conspicuous externally. In order to examine them, split the body of a grasshopper along the median line, carefully remove all the viscera, muscles, tracheæ, etc., from one half, and notice the flat, oval, semi-transparent *tympanum* upon the side of the first abdominal segment. Cut it out with a pair of fine-pointed scissors; place it on a watch-glass, cover it with water, and carefully dissect away any tracheæ which may adhere to its inner surface. Examine it with a hand-lens or a low power of the microscope, and notice:—

1. A thickened rim or bow (Fig. 140, *a*) which forms the margin of three sides of the organ. This rim is simply a greatly thickened portion of the ordinary chitinous integument of the body.

2. The space inside the rim is occupied by the thin, semi-transparent tympanum (*b*), which is also a part of the chitinous integument.

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3. On that side which is not surrounded by the rim the tympanum is continuous with the ordinary integument.

4. On this side notice the spiracle (*d*), and, below this, the auditory nerve (*l*) passing from the third thoracic ganglion to the ear.

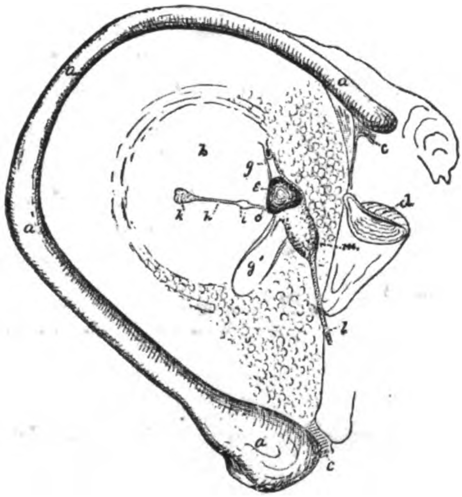

FIG. 140.

FIG. 140. — Left auditory organ of a grasshopper (Stenobothrus rufus), viewed from within and magnified about ten diameters. This figure is a combination of three of the figures given by Oscar Schmidt (*Die Gehör-organe der Heuschrecken,* Arch. f. Mih. Anat. xi. 195, 1875).

a. Thickened margin of the tympanum. *b.* The tympanum. *c.* Muscles. *d.* Spiracle. *e.* Cone-shaped prominence. *g.* Its lateral prolongation. *g'.* Thickened fold of the tympanum. *h.* Tube leading to the triangular chamber. *k.* Triangular chamber. *i.* Small ganglion. *l.* Auditory nerve. *m.* Auditory ganglion.

5. A number of small muscles (*c*, *c*) are attached to the free ends of the rim, and are so arranged that when they are contracted the tension of the tympanum is diminished.

6. That side of the tympanum which is nearest the

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spiracle is the thickest, and its inner face is covered by a mass of spherical pigmented cells.

7. Near the centre of the tympanum there is a much thinner, nearly circular space, near the centre of which there is a triangular chamber (*k*) or cavity hollowed out in the substance of the tympanum.

8. From this chamber a tube (*h*) runs towards the spiracle, and opens internally near the letter *i*, from which point the tube is continued for a short distance as an open channel (*c*).

9. At *e*, near the end of this channel, the tympanum is greatly thickened and folded upon itself so as to form a hollow, cone-shaped prominence (*e*), which projects from the inner surface of the tympanum, while its cavity opens on the outer surface at *g*.

10. Below this prominence the tympanum is folded so as to form a channel (g^1).

11. Soon after it enters the ear cavity the auditory nerve (*l*) expands to form the bell-shaped auditory ganglion (*m*), which rests upon one side of the cone-shaped prominence (*e*), and is also continued upwards and downwards around the prominence. Below the prominence the ganglion gives rise to a small nerve, which passes into the channel *c*, and then enlarges to form an accessory ganglion (*i*), and passes from this through the tube (*h*) to the triangular chamber (*k*), where it enlarges to form a small triangular ganglion, which may be called the tympanic, since it is entirely surrounded by the chitin of the tympanum, except at the point where the nerve joins it.

The microscopic structure of the ganglia appears to vary somewhat in the different genera of the family. In Stenobothrus (according to Schmidt, Arch. f. Mik. Anat. xi. 195) fine fibres radiate from the tympanic ganglion and

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pass out into tubular spaces in the tympanum, where they terminate in small expansions, which appear to be the parts of the apparatus which are directly affected by the vibrations of the membrane. The microscopic structure of the larger ganglion (*m*) has been investigated (Ranke, Zeit. f. Wiss. Zool. xxxv. 1875, p. 143) in the genus Acridium.

FIG. 141. — Auditory ganglion of Acridium cerulescens, greatly magnified, after Ranke (*Beiträge zu der Lehre von den Uebergangs-Sinnesorganen*, Zeit. Z. Wiss. Zool. xxv. 1875, p. 143).

B. The auditory nerve and ganglion. *a.* External or peripheral face of the ganglion. *b.* Transparent portion. *c.* Pigmented portion. *d.* Auditory nerve. *e.* Fusiform bodies. *f.* Their stems. *g.* Layer of nuclei. *h.* Ganglion cells. *A.* Termination of a nerve fibre, very highly magnified. *a.* Fusiform body. *b.* Stem. *c.* Nucleus. *d.* Fibre which connects it to the ganglion cell. *e, f.* Nerve fibre.

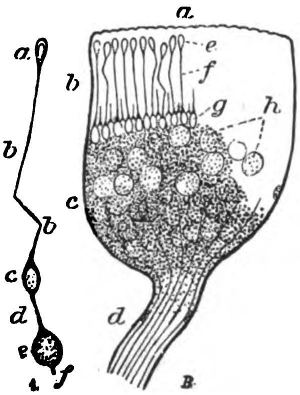

FIG. 141.

12. According to this author, when the fresh ganglion is removed with needles from the surface of the tympanum of a grasshopper which has just been killed, and is placed in water on a slide and examined with a high power of the microscope, it is seen to be a bell-shaped structure (Fig. 141, *B*), in which are seen: —

a. The flattened peripheral surface (*a*), which normally lies in contact with the side of the cone-shaped prominence (Fig. 140, *e*).

b. The opposite rounded end.

c. The auditory nerve (*d*, Fig. 141), in which are to be seen: —

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(i.) The external sheath, with a few scattered nuclei upon its inner surface.

(ii.) The nerve, made up of a number of parallel fibres.

(iii.) These fibres may be traced into the ganglion, where they diverge from each other.

d. In the ganglion are: —

(i.) An outer transparent layer (*b*).

(ii.) A more opaque pigmented portion (*c*).

e. In the transparent portion are a number of highly refractive spindle-shaped bodies (*e*) with an outer rounded and an inner pointed extremity.

(i.) From the pointed end a fine, transparent, highly refractive fibre or rod (*f*) runs backwards, and may be traced nearly to the opaque portion of the ganglion.

f. On the anterior or distal surface of the opaque portion are a number of highly refractive oval bodies, the nuclei (*g*), arranged in a single row.

g. Back of these the mass of the opaque portion (*i*) of the ganglion is made up of crowded, spherical, somewhat granular ganglion cells (*h*), which are embedded in the granular substance of the ganglia, so that their outlines are not readily seen.

13. When the fresh ganglion is torn to pieces with needles, and the fragments examined with a high power, —

a. The spindle (Fig. 14, *A*, *a*) is seen to be a sharply defined body, made up of a transparent, highly refractive outer layer and a central granular core.

b. The pointed end of the spindle is continuous with the rod (*b*), and wherever the latter has been disturbed by the needles it is bent abruptly at an angle, thus showing that it is brittle and inflexible. The rod is transparent throughout the greater part of its length.

c. The posterior or inner end of the rod is opaque,

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granular, and continuous with a thin layer of granular protoplasm which invests the nucleus (*e*).

d. The latter is united by a short thread of granular protoplasm (*d*) to a ganglion cell (*e*), from the opposite end of which a nerve fibre (*f*) originates and runs down into the auditory nerve, and so to the third thoracic ganglion of the central nerve cord.

XXV. THE GENERAL ANATOMY OF A LAMELLIBRANCH.

THE following description is strictly applicable only to the fresh-water genus Anodonta, but any of the Unionidæ may be used for laboratory work, or if these are not to be had, the common long clam (Mya) or the round clam (Venus) may be used instead. Mya and Venus may be obtained of the fish-dealers in most of our cities, and Unio and Anodonta may usually be found in abundance in most ponds, lakes and streams. Either fresh or preserved specimens may be used. The valves of the shell of a living specimen are usually so tightly closed that some difficulty may be found in opening them. The best plan is to place them in warm water — about fifty-five or sixty degrees centigrade — for a few minutes. The muscles will then relax enough to allow the blade of a scalpel to be introduced to cut their attachment to the inside of the shell. After the specimen has been opened it should be placed in a dish of water, or water and alcohol, and all the dissecting should be performed while the specimen is submerged. The addition of alcohol to the water is a great help, since transparent parts are rendered opaque and visible by it, and it also coagulates the slime which covers the body, and thus facilitates the work.

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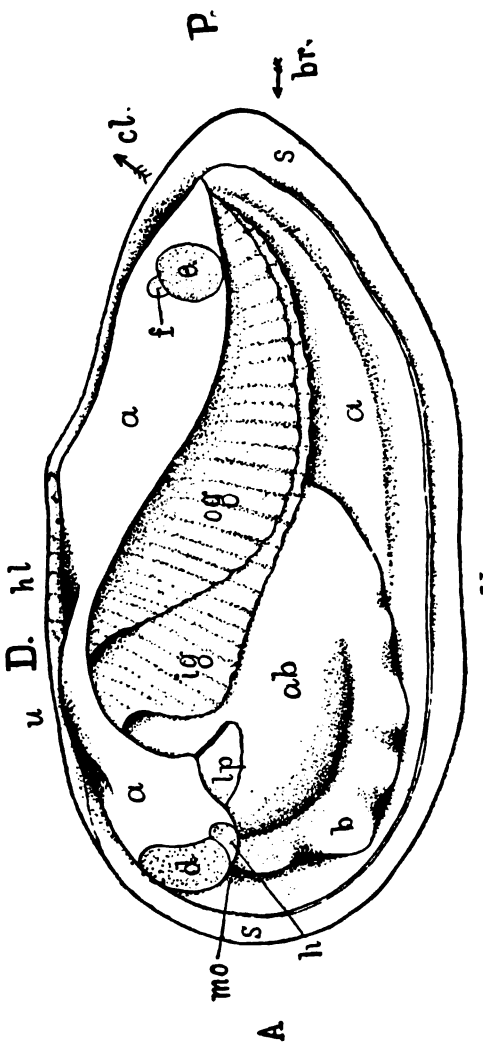

FIG. 142.

FIG. 142. — Anodonta with the left valve of the shell and most of the left lobe of the mantle removed, to show the gills and abdomen. (Drawn from nature by S. Garman.)

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Explanation of letters for Fig. 142:—

A. Anterior end. *P*. Posterior end. *D*. Dorsal surface. *V*. Ventral surface. *a*. Mantle. *ab*. Abdomen. *b*. Foot. *br*. Branchial siphon. *cl*. Cloacal siphon. *d*. Anterior adductor muscle. *e*. Posterior adductor muscle. *f*. Posterior foot-retractor muscle. *h*. Anterior foot-retractor muscle. *hl*. Hinge ligament. *ig*. Inner gill of left side. *lp*. Labial palpi. *mo*. Mouth. *og*. Outer gill of left side. *s*. Right valve of shell. *u*. Umbo.

I. Examine first the outer surface of the shell and notice :—

a. The two elongated irregularly oval pieces or *valves* of the bivalve shell, one on each side of the body. Notice the thin layer of horny-brown, or red or olive-green *epidermis*, which covers those parts of the shell which have not been eroded.

b. On the surface of each valve the concentric *lines of growth*.

c. Near the middle of one side of each valve, an area, usually much eroded, around which the successive lines of growth are arranged; this, the oldest part of the shell, is the *umbo* or beak (Fig. 142, *u*) and the margin upon which it is situated the *dorsal* margin (Fig. 142, *D*).

d. Notice that the ventral margins of the valves, and their ends, are free from each other, as well as the greater portion of their dorsal margins.

e. Near the umbones they are united by the brown horny *hinge-ligament* (Fig. 142, *hl*).

f. The ligament is posterior to the umbones, and thus furnishes a means of distinguishing the somewhat pointed posterior end of the shell (*P*) from the more regularly rounded anterior end (*A*).

g. Watch a living mussel in the water, and notice the soft white margins of the mantle which prctrude slightly beyond the edges of the shell.

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h. In some specimens the large white fleshy foot (Fig. 142, *b*) will be seen to project from between the anterior ventral edges of the shell.

i. At the posterior end of the body the margins of the mantle are so modified as to form two imperfect tubes which project beyond the shell, the siphon tubes.

1. One of these, the *cloacal siphon* (Fig. 142, *cl*), is on the dorsal surface of the shell, between the ligament and the posterior end.

2. The other or *branchial* siphon (Fig. 142, *br*) is at the posterior end of the body, and its edges are set with a fringe of small sensitive tentacles.

3. Fill a long slender glass tube with some colored substance, such as finely powdered carmine in water. Place the lower end of the tube near the cloacal siphon, and allow a few drops of the fluid to escape. It is violently driven away from the mouth of the siphon. When the coloring matter is allowed to escape near the lower or branchial siphon it is sucked in, and in a short time some of it is driven out through the upper or cloacal opening; thus showing that a continuous current of water, the branchial current, is passing in at the one and out at the other opening.

II. Before opening the specimen it is best to study the inner surface of another shell, noticing:—

a. The large kidney-shaped scars for the attachment of the two *adductor muscles*.

b. A line which runs from the lower edge of the scar of the anterior adductor along the ventral edge of the valve to the scar of the posterior adductor. This *pallial line* is the area of attachment of the edge of the mantle to the margin of the shell.

c. Above and in front of the scar of the posterior ad-

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ductor is a much smaller scar, the point of attachment of the *posterior retractor muscles* of the foot, and near the scar of the anterior adductor are two small marks, indicating the points where the *anterior foot retractors* and the *foot protractors* are attached.

d. In the shell of Unio, notice the *hinge teeth*, which are situated upon the thickened dorsal edges of the valves.

1. The anterior or cardinal teeth are situated under the umbones, and are very irregular in shape. In most species there is one in the right and two in the left valve.

2. Back of these and under the hinge ligament are the *long, narrow, lateral teeth;* one in the right and two in the left valve.

e. The shell is made up of three layers.

1. The horny epidermis which covers the outer surface of the valves, and is reflected over their free edges into the mantle.

This layer is directly continuous with the hinge ligament.

2. The pearly layer which covers the greater portion of the inner surface. When carefully examined with a lens this layer is seen to be made up of very thin, flat, superimposed layers of pearl, the edges of which are visible as fine sinuous lines on the inner surface.

3. The darker prismatic layer is between these two, and is exposed only along the edge of the inner surface. When examined with a lens it is seen to be made up of polygonal prisms, placed perpendicular to the surface of the shell.

f. Examine a fractured surface with a hand-lens, and notice these layers, as seen in section.

III. In order to expose the body, raise one valve of the

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shell by separating the mantle from it along the pallial line, with the handle of a scalpel, and then cutting the two adductor muscles and the foot retractors. As soon as these muscles are cut, notice that the elasticity of the hinge ligament throws the ventral margins of the shells apart. In the animal thus exposed, notice: —

a. The semi-transparent *mantle* (Fig. 142, *a*), which lines the inner surface of the shell.

b. The thickened muscular margin.

c. The band of small mantle muscles which were attached to the shell along the pallial line.

d. The adductor and retractor muscles.

e. Notice that the two lobes of the mantle are united along the region of the hinge. Above the anterior adductor they separate, and they are free from each other along their anterior, ventral, and posterior margins as far as the branchial siphon, which is simply an enlargement of the narrow space between them. Above this opening they unite to form the lower edge of the cloacal siphon, and they are then separated as far as the posterior end of the hinge ligament.

f. On the dorsal surface of the body, a little anterior to the posterior adductor, notice a region where the mantle is quite thin and transparent — the pericardial chamber. Watch this chamber carefully, and notice through its wall the pulsating heart.

g. On the middle line of the upper posterior face of the posterior adductor muscle, notice the small *rectum* (Figs. 143 and 144, *m*), which opens by the *anus* into the cloacal siphon.

h. Raise up the loose portion of the mantle, and notice the large *branchial* chamber into which the branchial siphon opens. In this chamber notice: —

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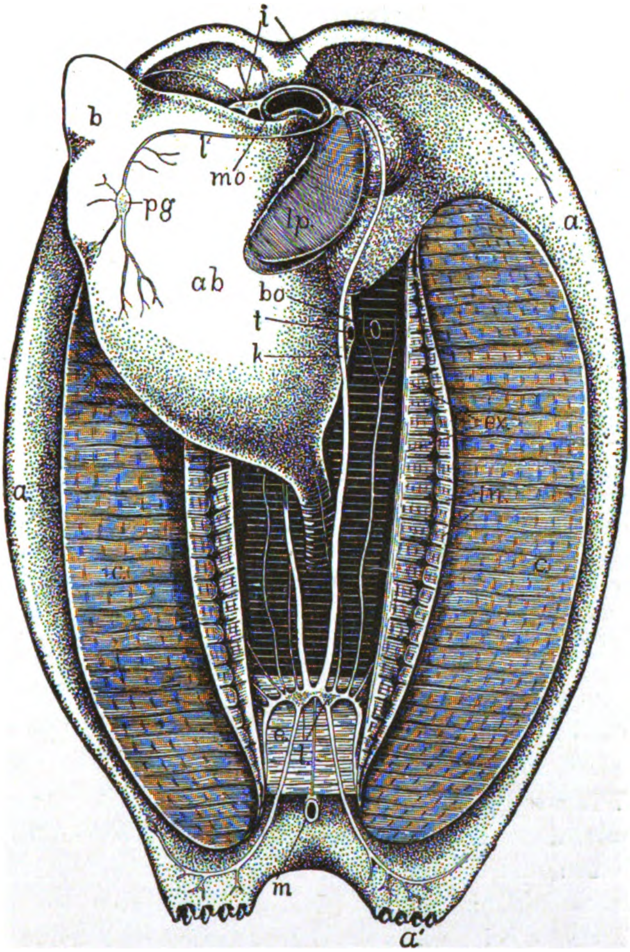

FIG. 143.

FIG. 143. — Semi-diagrammatic view of Anodonta, seen from below with the inner gills separated from each other, to show the cloacal chamber, the posterior adductor muscle and the floor of the organ of Bojanus.

a. Mantle. *a*[1]. Branchial siphon. *ab.* Abdomen. *b.* Foot. *bo.* External opening of the organ of Bojanus. *c.* Gills. *e.* Posterior adductor

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muscle. *ex.* Outer lamella of inner gill. *i.* Cerebral ganglia. *in.* Inner lamella of inner gill. *j.* Cerebro-pedal commissure. *k.* Cerebro-visceral commissure. *l.* Parieto-sphlancnic ganglia. *lp.* Labial palpi. *m.* Rectum. *mo.* Mouth. *pg.* Pedal ganglia. *t.* Reproductive orifice.

1. The four long flat *gills* (Fig. 142, *o*, *g*, *i*, *g*; Figs. 143 and 144, *c*), two on each side, which are attached to other structures above, but hang down into the branchial chamber, like longitudinal curtains, with their ventral margins free.

2. Hanging down into the space between the gills is the soft *abdomen* (Figs. 142 and 143, *a*, *b*). Its walls are muscular, and the anterior and posterior foot retractor muscles form its anterior and posterior faces, and suspend it between the valves of the shell.

3. On its ventral surface these muscles unite to form the *foot* (Figs. 142, 143, and 144, *b*), which is usually quite small in a specimen which has been opened, but is capable of great extension, and usually protrudes in the living animal from between the ventral edges of the shell.

4. Notice that the inner gill of each side is a little larger than the outer, and its anterior edge rests between a pair of flat, triangular, lip-like processes, the *labial palps* (Figs. 142 and 143, *l*, *p*).

5. Above the foot, and just below the anterior adductor muscle, these palps are continued across the front of the abdomen, and between them is the large oval opening of the *mouth* (Figs. 142 and 143, *m*, *o*).

i. Pass a bristle into the dorsal siphon and notice that it lies above the gills, and does not pass into the branchial chamber. Remove the animal from both valves of the shell, and cut, with a pair of scissors, along the line where the inner edges of the inner gills join each other. Spread the specimen out, under water, as shown in Fig. 143 and

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notice that the bristle has passed into a chamber which is dorsal to the gills, and which is known as the *cloacal chamber*.

j. The *gills*. Notice that the upper edge of each gill carries a row of openings which communicate with the cloacal chamber. These are the openings of the vertical water tubes. Pass a bristle into one of the water tubes, and notice that this ends blindly at the free ventral edge of the gill. Notice also that it is separated by vertical partitions from the water tubes before and behind it. When the microscopic structure of the gill is studied as described in Section XXVII. each water tube will be seen to communicate with the branchial chamber through a great number of microscopic ciliated openings, the *branchial slits*, which cover the flat surfaces of the gill. The water which is drawn through the branchial syphon into the branchial chamber is driven by the cilia through the branchial slits into the water tubes, and as these are filled the water flows up into the cloacal chamber, and is discharged from the body through the cloacal siphon.

1. Each of the four gills consists of two flat plates, the outer and inner lamellæ (Fig. 143, *ex* and *in*), and these are united to each other by vertical partitions, which separate the water tubes from each other.

2. The upper edge of the outer lamella of each outer gill is united to the mantle.

3. The upper edge of the inner lamella of the outer gill is united to that of the outer lamella of the inner gill, and the anterior third is also united to the wall of the abdomen.

4. The inner lamellæ (*e*) of the inner gills are united to each other for about one third of their length at the posterior end of the body, but at the posterior end of the abdomen they separate and pass one on each side of it.

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In some sub-genera they are united to the abdomen from this point to their anterior ends, but in Anodon and most Unios they are free for a small part of their length, so that there is a direct communication between the branchial and cloacal chambers.

k. The *Nervous System*. After the gills have been separated from each other, as described in *i*, the lower surface of the posterior adductor muscle (Fig. 143, *e*) will be seen near the posterior end of the body.

1. Near the anterior edge of the muscle a pair of orange-brown masses, the *parieto-splanchnic ganglia* (Fig. 143 and 144, *l*) will be seen, covered by a transparent layer of integument. Carefully dissect this off, to expose the ganglia and the nerves which run from them, noticing: —

(i.) A nerve which runs backwards to the rectum (*m*).

(ii.) A pair of large *pallial nerves*, which run backwards and outwards to innervate the edges of the mouth.

(iii.) A pair of large *branchial nerves*, which run to the gills.

(iv.) A number of small nerves, which run forwards and outwards from the ganglion to adjacent parts.

(v.) Near the middle line a pair of much larger trunks, the *cerebro-visceral commissures* (Figs. 143 and 144, *k*). These can be traced forward for some distance, but more anteriorly they pass into the substance of the abdomen (*ab*), and cannot be traced without dissection. Carefully dissect them out as far as the anterior edge of the abdomen.

2. Each of them will be found to join a small *cerebral* ganglion (Figs. 143 and 144, *i*) The two cerebral ganglia lie at the sides of the mouth under the labial palpi. Each gives rise to pallial nerves, which pass to the mouth;

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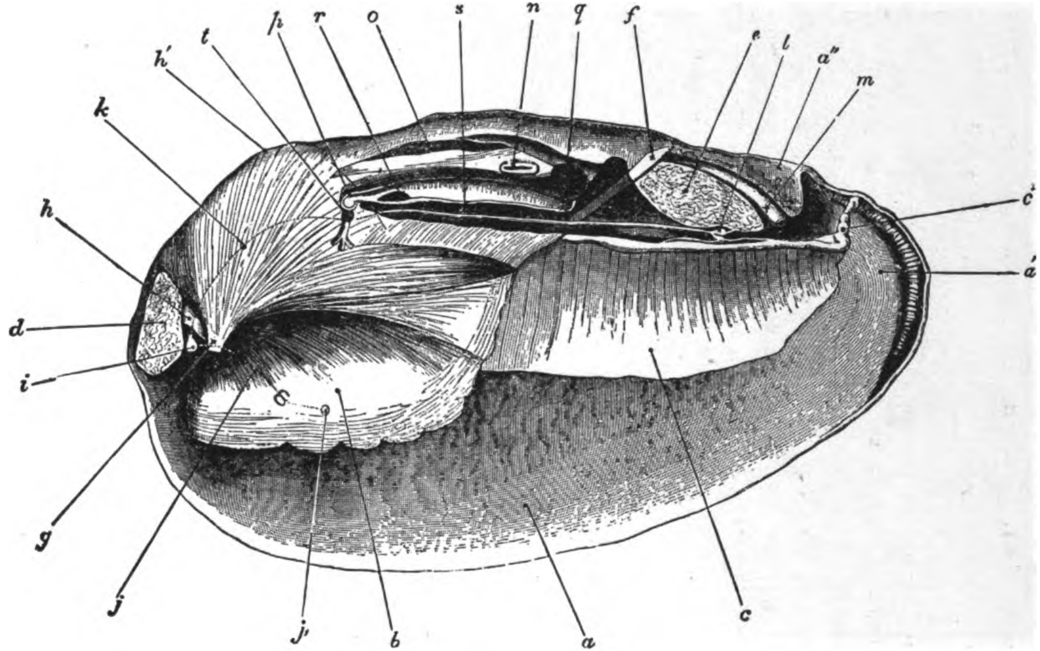

Fig. 144.

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FIG. 144. — Anodonta cygnea, seen from the left side. The mantle and gills of the left side, the labial palpi, part of the pericardium and part of the organ of Bojanus have been removed. (From Rolleston, *Forms of Animal Life*, Plate V.)

a. Right mantle lobe. *a'*. Branchial siphon. *a''*. Dorsal edge of mantle. *b*. Foot. *c*. Gills. *d*. Anterior adductor. *e*. Posterior adductor. *f*. Posterior foot-retractor. *g*. Foot-protractor. *h*. Anterior foot-retractor. *i*. Cerebral ganglia. *j*. Cerebro-pedal commissure. *j'*. Auditory organs. *k*. Cerebro-visceral commissure. *l*. Parieto-splanchnic ganglia. *m*. Rectum. *n*. Heart. *o*. Pericardium. *p*. External opening of organ of Bojanus. *q*. Channel of communication between its glandular and non-glandular portions. *r*. Opening between glandular portions. *s*. Glandular portion. *t*. Reproductive orifice.

labial nerves which pass to the palpi, and to three commissures.

(i.) One of these is the cerebro-visceral commissure, which has just been traced.

(ii.) Another is the *cerebral commissure*, which passes in front of and dorsal to the mouth, and joins the two cerebral ganglia to each other.

(iii.) The third is the *cerebro-pedal commissure* (Figs. 143 and 144, *j*), which runs downwards along the anterior edge of the abdomen, under the muscles.

3. In the foot these commissures bend backwards, and join the pair of *pedal ganglia* (Fig. 143, *pg*). These two ganglia are fused with each other on the median line, and they are embedded in the muscles of the foot in such a way that they cannot be found without careful dissection. They are at some distance from the outer surface, and very near the inner or abdominal surface of the foot. They give rise to a number of nerves which pass to the muscles of the foot.

4. If possible find a very young specimen of Unio or Anodonta, one less than quarter of an inch long, and having cut out the foot, place it upon a glass slide, and

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gently pressing it under a cover, examine it with a power of about eighty diameters. Having found the pedal ganglion, search carefully for the auditory organs. These are a pair of spherical microscopic pouches, each of which contains a round, highly refractive calcareous ossicle. After the auditory organ has been found in a small specimen, carefully dissect out the pedal ganglion of a full-grown specimen under the microscope, and try to find the auditory organs and the small nerves which join them to the cerebro-pedal commissures. If a young Unio or Anodonta cannot be found for microscopic examination, any other very small marine or fresh-water lamellibranch will answer.

m. The *reproductive* and *renal openings*. On each side of the abdomen, above the cerebro-visceral commissure, notice a small slit (Fig. 143, *t*), through which the reproductive organs open into the cloacal chamber, and just above and close to these a second pair of openings (Fig. 143, *bo*), the external apertures of the renal organs, or *Organs of Bojanus*.

n. Open a fresh specimen, and remove the body from the shell, exercising great care to avoid injuring the soft parts. Place it in water with the dorsal surface above, and notice on the middle line the transparent *pericardium* (Fig. 144, *o*). Carefully open this, and notice that the dark-colored intestine runs through it longitudinally. The greater part of the cavity of the pericardium is occupied by the transparent heart (Fig. 144, *n*), which consists of a median *ventricle* wrapped around the intestine, and two lateral *auricles*.

1. The *ventricle* is a large oval transparent pouch which gives rise to an *anterior aorta* dorsal to the intestine, and a *posterior aorta* ventral to the intestine.

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2. On each side of the ventricle is a large transparent *auricle*, which receives the blood from the bases of the gills and drives it into the ventricle.

3. Carefully study the pulsation of the heart. The auricles swell irregularly and become filled with the transparent, colorless blood from the gills, and they then contract, slowly and irregularly, while the ventricle becomes distended. A slow wave of contraction then runs from one end of the ventricle to the other, and forces the blood into the aorta.

4. Notice that the pericardium is also filled with blood.

5. Open the ventricle, and notice the lip-like valves, which prevent the blood from returning to the auricles.

o. The *venous sinus* and the *renal organs.*

Cut the intestine, and the auricles, so that they may be removed from the pericardium, thus exposing its floor, and the organs which lie below it.

1. The *venous sinus* is a long chamber, with a transparent roof, which lies along the middle line of the floor of the pericardium, into the cavity of which it opens, near its anterior end, by a single median aperture.

2. On each side of it is one of the *renal organs*, or *organs* of Bojanus. Each of these is a long tube, doubled upon itself so as to form an upper and a lower chamber. The upper chamber has thin, transparent walls, and is known as the *non-glandular portion* (Fig. 145, *a'*). Its anterior end bends downward, and opens at *l* in Fig. 145, into the cloacal chamber. The lower chamber has thick, dark-colored, folded walls, and is known as the glandular portion of the organ. At its anterior end it opens into the cavity of the pericardium (Fig. 145, *n'*), at *i*. Anteriorly, the cavity of the non-glandular portion is separated from that of the glandular portion, but posteriorly the two communicate with each other.

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(i.) The opening from the pericardium into the glandular portion will be found at the anterior end of the former, just below the point where the intestine enters it. Pass a bristle through it, into the non-glandular portion.

(ii.) The non-glandular portion lies above and outside of the glandular portion. Open it and find, at its anterior end, the external opening into the cloacal chamber. Notice, at its posterior end, its communication with the dark-colored, thick-walled, glandular portion.

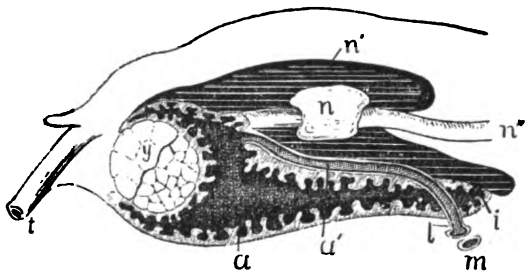

FIG. 145.

FIG. 145.—Diagram of Bojanus organ of Unio pictorum. (From Bronn, Klassen und Ordnungen, *Malacozoa*. Tab. xxxii. Fig. 11.)

a. Glandular portion of organ of Bojanus. *a'*. Non-glandular portion. *i*. Opening from pericardium into glandular portion. *l*. External opening of non-glandular portion. *m*. Reproductive orifice. *n*. Ventricle. n^1. Pericardium. *t*. Rectum.

(iii.) Cut through the floor of the non-glandular portion, and lay open the glandular portion. Notice the bristle which has been passed into it from the pericardium. Notice that the glandular portion runs back much further than the non-glandular portion, and becomes expanded at its posterior end to form a large pouch, which rests against the posterior adductor muscle.

3. The blood from the various parts of the body finds its way to the venous sinus, some of it passing through

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the pericardium; it then passes through the glandular walls of the renal organs to the gills, and is then returned to the auricles, to be again driven to the various organs of the body.

p. The *Digestive Organs*. It is very difficult to trace these in a fresh specimen, and one which has been hardened in alcohol should therefore be used.

1. Notice the mouth, on the middle line of the body, under the anterior adductor muscle, and between the labial palpi.

2. Carefully dissect it out and trace it upwards to the small, irregular *stomach*.

3. Around the stomach notice the compact, dark, brown *liver*, which opens, by several irregular apertures, into the stomach.

4. The *intestine* is a long, delicate tube, which is embedded in the light-colored reproductive organs, which form the greater part of the abdomen. It first runs downwards from the stomach nearly to the foot; then upwards nearly to the dorsal surface; then down again nearly to the foot, where it bends forwards and then upwards to leave the abdomen and enter the pericardium. It passes through the ventricle, and, leaving the pericardium at its posterior end, passes over the posterior adductor muscle.

5. The posterior end of the intestine, or the *rectum*, bends around the adductor muscle, to open at the *anus* into the cloacal chamber, close to its aperture, so that the fæces are swept out of the mantle cavity by the current of water from the gills.

q. The *reproductive organs*. These make up the greater part of the substance of the abdomen, and are alike in form in both sexes. They vary in size with the season,

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being large at the time of reproduction, and very small immediately afterwards. They open into the cloacal chamber, as already noticed.

When the eggs pass out of the ovary they are conveyed into the water tubes of the outer gills, which serve as brood pouches, in which the developing eggs and young are carried.

XXVI.—THE EXAMINATION OF TRANSVERSE SECTIONS OF UNIO OR ANODONTA.

The general arrangement and relations of the parts in Unio or Anodonta will be most easily understood by the study of a series of transverse sections of a hardened specimen.

The sections which are figured are from Unio purpurea, but any species will answer.

An animal which has been preserved in strong alcohol will be found to be in fair condition for making sections, but one which has been hardened in chromic acid is better. The animal should be placed, alive, in its shell, in a quart or more of one per cent chromic acid, and allowed to remain for about forty-eight hours. After this time it should be removed to seventy per cent alcohol, and allowed to remain for a day or two. It may then be preserved in ninety per cent alcohol, and kept until it is wanted.

In order to cut the sections, the body must be carefully removed from the shell without cutting or breaking it. This may be done by forcing the valves of the shell far enough apart to introduce the handle of a scalpel, which may be used to force away the mantle and muscles from their attachment to the shell. The body may now be

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placed in a basin of water, and sliced vertically with a razor at intervals of half or one-third of an inch. The sections should then be preserved for study under alcohol in a shallow dish or saucer. The more instructive sections are: one through the posterior portion of the posterior adductor muscle; one through the space between the posterior adductor and the heart; one through the heart; one through the middle of the abdomen; and one through the anterior portion of the abdomen.

I. *A section through the posterior adductor muscle.*

In this, as in all the other sections, two main chambers or cavities are to be noticed.

a. The *mantle cavity* (Fig. 146, *d*, *h*), which is widely open below, and contains the gills (Fig. 146, *e*, *f*).

b. Above this, notice the *body cavity*, which in this section is almost entirely filled by the adductor muscle (Fig. 146, *g*), the rectum (Fig. 146, *p*), and connective tissue.

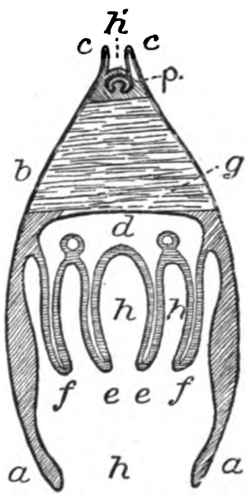

FIG. 146.

FIG. 146. — Diagram of a vertical section of the body of Unio purpurea in the region of the posterior adductor muscle. (Drawn from nature by W. K. Brooks.)

a, *a*. Mantle lobes. *b*. Glandular epithelial layer of mantle. *c*. Dorsal lobes of mantle. *d*. Cloacal chamber of mantle cavity. *e*, *e*. Inner gills. *f*, *f*. Outer gills. *g*. Posterior adductor muscle. *h*. Branchial chamber. *h'*. Dorsal portion of mantle cavity. *p*. Rectum.

c. Above the intestine is what appears to be another small cavity (Fig. 146, *h'*), but if the posterior end of the section be examined, it will be found to be part of the

mantle cavity, with which it is continuous, behind the adductor muscle, so that a section of this region would show a single cavity containing the gills, and open both ventrally and dorsally.

d. The sides of the mantle cavity are formed by the mantle lobes (Fig. 146, *a*, *a*), each of which is made up of: —

1. An outer integument, or glandular epithelium, which is normally in contact with the inside of the shell, and by which the shell is excreted.

2. An inner integument, or ciliated epithelium, which faces inwards and lines the mantle cavity.

3. A loose network of muscular fibres and connective tissue, which fills the space between these two layers. (The embryology of the lamellibranchs, as well as the study of sections, shows that this space is a part of the body cavity, which has become filled with connective tissue.)

e. If the two layers of integument be traced upwards, they will be found to diverge in the upper part of the section, the outer glandular layer passing over the surface of the adductor muscle (Fig. 146, *g*), as a thin, transparent pellicle (Fig. 146, *b*), the inner ciliated layer, on the contrary, is reflected inwards below the adductor muscle, and thus forms the roof of the mantle cavity (Fig. 146, *d*).

The body cavity, with its contained organs, is thus entirely surrounded by integument.

f. The *body cavity.*

This is comparatively unimportant in this section; it contains: —

1. The adductor muscle (Fig. 146, *g*).

2. The intestine (Fig. 146, *p*), with its horseshoe-shaped cavity and ventral ridge, which is mushroom-shaped when seen in section.

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3. If the section has passed through the parieto-splanchnic ganglia, these will be seen between the lower surface of the muscle and the roof of the mantle cavity, upon the middle line.

g. The *mantle cavity*.

This contains the gills, and is divided by them into two chambers.

1. The branchial chamber (Fig. 146, *h*), which is widely open below, but is bounded at the sides by the mantle lobes, and above by the gills.

2. The cloacal chamber (Fig. 146, *d*), which is bounded above by the adductor muscle; at the sides by the mantle, and below by the gills.

h. The *gills*. The four gill plates (Fig. 146, *e*,*f*), are so arranged as to form a double W, which separates the branchial from the cloacal chamber.

1. Note that the upper margin of the outer lamella of the outer gill (*f*) of each side is united to the surface of the mantle. It is important for a correct appreciation of the homology of the mantle cavity among the lamellibranchs, to bear in mind the fact that this union of the gills to the mantle is a character of secondary importance, which is lacking in the young of Unio and Anodonta, and in many adult lamellibranchs of other families.

2. The inner lamellæ of the inner gills (*e*) of the two sides of the body are united to each other at *d*, but the ridge thus formed is free dorsally.

3. The inner lamella of the outer gill of each side is united to the outer lamella of the inner gill, and the ridge thus formed is also free dorsally, and contains a small blood-vessel.

i. Make a drawing of the section, showing all these points.

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II. The *examination of a section between the posterior adductor muscle and the heart.*

a. Notice the mantle cavity (Fig. 147, *h*, *i*, *k*), in substantially the same position as in the preceding section: containing the gills (Fig. 147, *l*, *m*), and bounded at the sides by the mantle lobes (*a*, *a*), and above by the body cavity.

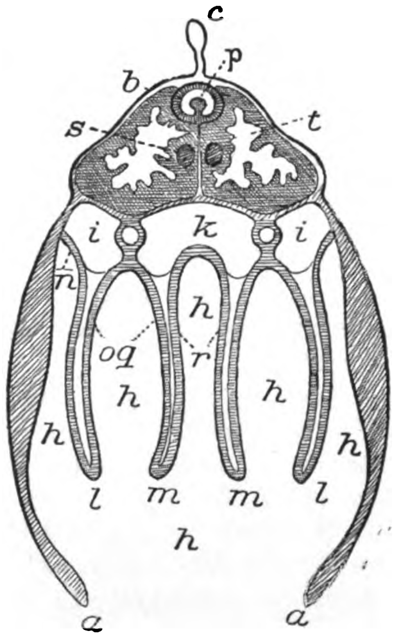

FIG. 147.

FIG. 147. — Diagram of a vertical section through the body of Unio purpurea, between the heart and the posterior adductor muscle. (Drawn from nature by W. K. Brooks.)

a, *b*, *c*, and *h*. as in Fig. 146. *i*, *i*. Cloacal tubes of outer gills. *k*. Cloacal tube of inner gills. *l*. Outer gills. *m*. Inner gills. *n*. Outer lamella of outer gill. *o*. Inner lamella of outer gill. *q*. Outer lamella of inner gill. *r*. Inner lamella of inner gill. *s*. Retractor muscles of foot. *t*. Glandular portion of organ of Bojanus.

b. The body cavity is of about the same size as in the previous section; somewhat triangular in shape, and occupying the dorsal portion of the section.

1. On the median line of the body cavity, close to the dorsal surface, notice the intestine (Fig. 147, *p*), with horseshoe-shaped cavity and ventral ridge.

(i.) The intestine is surrounded by a layer of connective tissue, which is united above to the dorsal portion of the integument.

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(ii.) A thin plate of connective tissue may also be traced downward below the intestine, as a sort of ventral mesentery, which connects the intestine to the integument of the roof of the mantle cavity, and thus divides the body cavity into halves.

2. On each side of this mesentery, notice the sections of the *foot-retractor muscles* (Fig. 147, *s*).

3. The remainder of the body cavity is filled, on each side of the partition, by a dark-colored, glandular organ, with very thick, delicate, plicated walls, enclosing an irregular cavity (Fig. 147, *t*). This structure is the glandular portion of the *organ of Bojanus*. Notice that the halves of this organ are entirely separated by a partition.

4. The body cavity is limited below, as in the preceding section, by the ciliated layer of the integument of the mantle.

c. The *mantle cavity*.

This contains the gills, and is now divided, by the attachment of the gills to the body, into four chambers (Fig. 147, *h*, *i*, *i*, *k*).

1. The lower or branchial chamber (*h*) presents substantially the same features as before.

2. The cloacal chamber (*d*, of Fig. 146), is now divided into three chambers.

(i.) A central chamber (*k*) which lies above the two inner gills, on the median line.

(ii.) Two lateral chambers (*i*, *i*) which lie above the outer gills, and which may be called the cloacal tubes of the outer gills.

d. The *gills*.

1. Note that the upper edge of the outer lamella (*n*) of each outer gill (*l*) is attached as before, to the mantle.

2. The inner lamellæ (*r*) of the inner gills (*m*) are united to each other, but not to the roof of the mantle cavity.

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3. The ridge formed by the union of the inner lamella (*o*) of the outer gill (*l*) to the outer lamella (*q*) of the inner gill (*m*) is now attached to the walls of the body cavity, thus dividing the cloacal chamber into three parallel tubes, which the previous section shows to be in communication with each other posteriorly.

e. Make a drawing of the section, showing all these points.

III. The *examination of a section through the heart.*

a. The mantle cavity is of substantially the same shape as in the previous sections, but it is now divided into five chambers (Fig. 148, *h*, *i*, *i*, *k*, *k*).

1. Of these the branchial chamber (*h*) is much the largest, and it contains not only the gills, but also the abdomen, which hangs suspended over the median line of the roof of the mantle cavity.

2. The cloacal tubes (*i*) of the outer gills are substantially as in the preceding section.

3. The median cloacal tube is now divided by the abdomen with two tubes (*k*, *k*) which may be called the cloacal tubes of the inner gills.

b. The *gills*.

1. The outer lamellæ of the outer gills are still attached to the mantle, and the ridge formed by the union of the inner lamella of the outer gill to the outer lamella of the inner gill is attached to the roof of the mantle cavity.

2. The dorsal edge of the inner lamella of the inner gill (*m*) is in this species free, so that the cloacal tube of the inner gill is in communication with the branchial chamber through the *branchial slit.* This is also the case in Anodonta and in most of the Unionidæ; but in certain sub-genera of the genus Unio there is no such slit, and the inner lamella is in this region united to the integument of

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the abdomen. The branchial slit is apparently for the purpose of allowing the water which has passed through the gills to pass back into the branchial chamber, and again

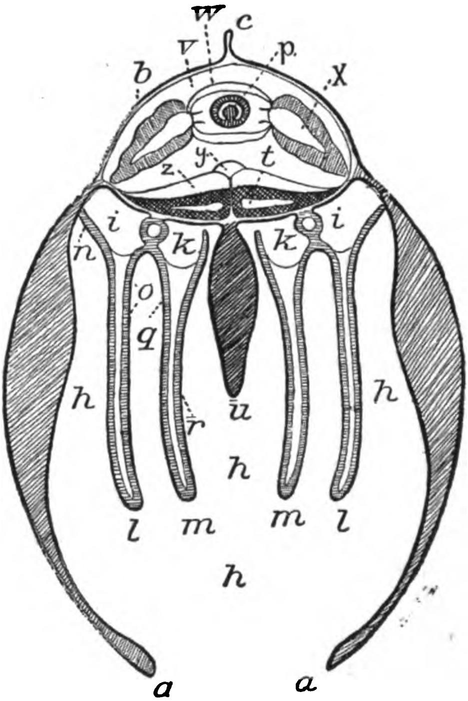

FIG. 148.

FIG. 148. — Diagram of a vertical section of Unio purpurea, passing through the heart. (Drawn from nature by W. K. Brooks.)

a to *t*. as in Fig. 146. *u*. Abdomen. *v*. Pericardium. *w*. Ventricle. *x*. Auricles. *y*. Sinus venosus. *z*. Non-glandular portion of organ of Bojanus.

through the gills, so that the branchial current need not be interrupted when the animal is out of water, with its valves closed; this arrangement is of importance in such marine

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lamellibranchs as live above low tide mark, and are out of water for some time every day.

c. The body cavity is now quite complicated and is divided into several chambers, and contains the heart, intestine, sinus venosus, Bojanus organ, and reproductive organs.

1. The larger portion of the body cavity is now occupied by the cavity of the pericardium (Fig. 148, *v*), which contains the heart and intestine.

2. The heart consists of a median ventricle (*w*) and two lateral auricles (*x*).

(i.) The ventricle is a delicate muscular cylinder, with a large cavity, upon each side of which is the aperture of communication with the auricle. This aperture is guarded by a pair of flaps or lips, which project inward and meet in front of the opening, and thus allow the entrance of the blood, but prevent its return.

(ii.) On each side of the ventricle is a large muscular auricle (*x*) with a small chamber, and thick spongy walls, which are capable, during life, of very great distension.

(iii.) In this section the outer ends of the auricles are united to the connective tissue of the body wall; but in a section a little anterior to this their cavities will be seen to communicate with the blood vessels of the gills.

3. In the centre of the ventricle notice the cut section of the intestine (*p*), with its horse-shoe shaped cavity.

4. The space between the pericardium and the roof of the mantle cavity is occupied by five chambers (Fig. 148, *t*, *y*, *z*), one median and two pairs.

In the region through which this section has passed these five chambers are entirely separated from the pericardium.

The median chamber (*y*) is the *sinus venosus*, and the four others are the two non-glandular chambers (*z*), of the organ of Bojanus, and its two glandular chambers (*t*).

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(i.) The *sinus venosus.* In the plane of this section this is a small, delicate walled chamber (y), on the median line, and its upper wall forms part of the floor of the pericardium.

(*a.*) Pass a bristle backward into the part of this chamber which has been cut off posterior to this section. The chamber will thus be found to end blindly behind.

(*b.*) Pass another bristle forward into the anterior part of the chamber, which will be found to widen, and at its anterior end an opening will be found through which its cavity communicates with that of the pericardium.

(ii.) On each side of the sinus venosus are the sections of the wide, flat, non-glandular, chambers of Bojanus (z). Their upper walls form part of the floor of the pericardium, and are thin and transparent.

(iii.) Below these, and meeting each other upon the median line below the venous sinus, are the thick-walled glandular chambers (t) of the organ of Bojanus.

(*a.*) Select the slice which has been cut off between this section and the one next behind it, and pass a bristle into this last chamber, and another into the non-glandular chamber of the same side; they will be found to pass out together, thus showing that the glandular and non-glandular chambers are in communication posteriorly.

(*b.*) Select the portion of the body anterior to this section, and introduce bristles into the same chambers and pass them as far forward as possible. No communication between the two will be found, but it will be seen that the non-glandular chamber does not lie above the glandular throughout its whole length, but that their anterior ends are side by side, and that each forms part of the floor of the pericardium.

(*c.*) If care is used, the bristle which has been passed

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forward into the glandular chamber may be made to pass through a small opening at its anterior end into the pericardium.

(*d*.) The bristle which has been introduced into the non-glandular part will, on the other hand, be found to pass through an opening which communicates with the cloacal chamber (*k*) of the inner gill.

5. The relations of these various chambers should also be examined in more anterior sections, especially one just anterior to the heart.

6. Suspended between the gills notice the large abdomen (Fig. 148, *u*).

(i.) The wall of this organ is a whitish integument which is composed of an external layer of epithelium and an inner layer of muscular fibres.

(ii.) At the bottom or free end of the abdomen the muscular fibres are more numerous, and form a muscular *foot*. In the plane of this section the foot is quite small or wanting, but further forward it is a conspicuous structure.

(iii.) The cavity of the abdomen is traversed in all directions by a loose white network of connective tissue, and the meshes of the network are almost entirely filled by the white or brownish reproductive organs. In various parts of different sections of the abdomen, sections of the various folds of the intestine will also be seen.

7. Make a sketch of the section, showing the above points.

IV. Sections through the middle and the anterior portion of the abdomen should also be examined and sketched, although they will be readily understood without explanation.

1. In that through the middle of the abdomen the ex-

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ternal apertures of the reproductive organs may be found. although they are so small that the section is not likely to pass through them. They are a pair of minute openings, on the sides of the upper portion of the abdomen, and are so placed that the reproductive elements are discharged into the cloacal tubes of the inner gills.

2. In the section through the anterior part of the abdomen, notice: —

(i.) The dark green liver which lies on the top and left side of the abdomen.

(ii.) The irregular cavity of the stomach, immediately below and almost surrounded by the liver.

a. The large openings of the bile ducts, upon its sides.

(iii.) The large muscular foot, upon the free end of the abdomen.

(iv.) The pedal ganglia embedded in the muscles of the foot on the median line.

XXVII. THE STRUCTURE OF THE LAMELLIBRANCHIATE GILL.

THE growing gills of an embryo and the simple gills of such a form as Mytilus must be studied in order to understand the highly complex gills of Unio or Anodonta. In the embryo each gill is, at first, a row of tentacles, growing out from the side of the abdomen into the mantle cavity, and having their tips free in this cavity.

As Cyclas gives birth to young throughout the whole spring and summer, embryos of this genus may be procured without difficulty for the study of the early stages of the gill.

I. The *examination of the gills of the Cyclas embryo.*

The various species of this genus are small fresh-water

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Lamellibranchs, from one-tenth to one-half an inch long. They may often be found in abundance near the surface of the mud at the bottoms of stagnant pools and ditches, and sometimes in running water. They are also frequently found climbing upon various water plants. They may be collected by washing the surface mud through the meshes of a fine wire net or strainer.

If a full-grown Cyclas be carefully opened in a watch-crystal full of water, its gills will usually be found to contain from four to ten or twelve embryos in various stages of development.

The largest embryos are very much like the adults in structure, and their gills are fully formed. They are, therefore, of no use for the present purpose, but they should be carefully studied, as familiarity with their appearance will facilitate the search for smaller ones.

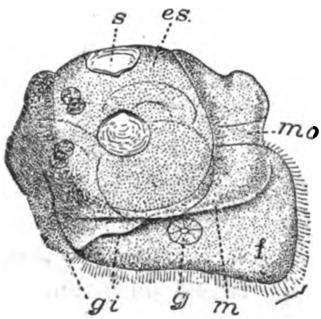

FIG. 149.

FIG. 149. — View of right side of a young Cyclas embryo, magnified about two hundred diameters. (Drawn from nature by W. K. Brooks.)

s. The two valves of the calcareous shell. *es.* The embryonic shell. *m.* The mantle. *mo.* The mouth. *f.* The foot. *g.* The pedal ganglia. *gi.* The gill tentacles.

a. If one in which the two calcareous valves of the shell have just made their appearance, as a pair of nearly circular patches upon the sides of the embryo, be placed upon a glass slide in a drop of water, and examined with a microscope, the following points may be noticed: —

1. The large, projecting, ciliated foot (Fig. 149, *f*), indicating the ventral surface of the animal.

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2. About half way between the foot and the shell the ventral border of the mantle is indicated by a horizontal line or fold (Fig. 149, *m*) upon the side of the body.

3. Below the posterior portion of this ridge or fold, notice that the body wall of the embryo is thrown into undulations, so as to form a series of two, three or more rounded prominences (Fig. 149, *gi*), the rudimentary gill tentacles.

(i.) The epithelium of these prominences is continuous with that of the general surface of the body, but much thicker, and is made up of a single layer of large cells.

(ii.) Above the base of each tentacle notice a loose mass of rounded mesoderm cells.

b. Find an embryo considerably more advanced, in which the two valves have grown downwards so as to cover up the abdomen and gills, and thus form a true mantle cavity. Place it upon a slide in water, and examine the gills as they are seen through the side of the transparent shell.

1. Each gill is now made up of a series of tentacles, arranged side by side, but not united to each other; their ventral ends are free, and their dorsal ends are attached to the side of the body.

2. The thick layer of epithelium which covers them may be traced down one side of each tentacle to the tip, then around and up on the other side to the point of attachment, where it passes to the adjacent tentacle.

3. The outer surfaces of the tentacles are covered with cilia.

4. Each tentacle is a hollow tube, closed below; and blood corpuscles may occasionally be seen in the cavities of the tentacles.

II. The *Gill of Mytilus*.

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The gill in such genera as Arca, Mytilus, and Modiola is about midway between the series of separate tentacles of the Cyclas embryo and the continuous lamella of Unio and Anodon, and enables us to understand how the latter is formed by the union of a row of tentacles. The common marine Mussel, Mytilus edulis, may be found in abundance attached by its byssus to piles and rocks near low tide mark. The general form of the gills may be studied in living or alcoholic specimens, but for making sections to show the minute structure, the gills should be carefully removed from the body and placed for twelve hours in a three-tenths of one per cent solution of chromic acid, and then transferred to seventy per cent alcohol; after they have remained in this for a day or two they may be transferred to strong alcohol, ninety per cent, and kept until they are wanted.

a. In an alcoholic specimen which has been carefully opened note that, as in Unio or Anodon, there is an inner and an outer gill upon each side of the body, and each gill consists, as in Unio, of an inner and an outer lamella.

1. As in Unio, the inner lamella (Fig. 150, *b*) of the outer gill, and the outer lamella (*c*) of the inner gill are united dorsally to each other and to the body wall.

2. The thickened ridge (*i*), formed by their union, contains a blood-vessel (*k*).

3. The outer lamella (*a*) of the outer gill, and the inner lamella (*d*) of the inner gill, unlike those of Unio, are free dorsally and end above in thickened ridges, which also contain blood-tubes (*k'*).

b. In a perfectly fresh living specimen, or in an alcoholic specimen which has been carefully preserved and opened, the surface of the gill is a broad, flat, vertically

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striated plate suspended in the mantle cavity by its upper margin, and terminating below in a continuous free edge.

When the gills are roughly handled in a living specimen, or one which has died in pure water, or in many alcoholic specimens, the lower edge of the lamella will be found to fray out, or break up into a great number of fine threads, and the gill now resembles a fringe rather than a flat plate. In the uninjured living animal these threads will soon be found to rearrange themselves in a continuous lamella, somewhat in the same way that the plumes of a ruffled feather soon reassume their natural positions.

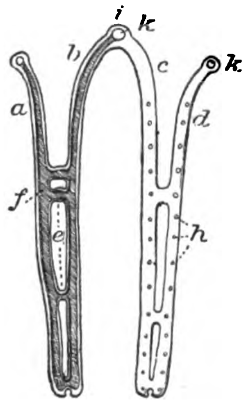

FIG. 150.

FIG. 150. — Diagram of the gills on one side of the body of Mytilus edulis, magnified about eight diameters. (Drawn from nature by W. K. Brooks.)

a. Outer lamella of outer gill. *b*. Inner lamella of outer gill. *c*. Outer lamella of inner gill. *d*. Inner lamella of inner gill. *e*. Inter-lamellar junctions. *f*. Cavity of tentacle, shown only on the left side. *h*. Inter-tentacular junctions. *i*. Line of attachment of gills to body. *k*, *k'*. Blood channels.

1. In an alcoholic specimen note that the threads or *gill tentacles* which compose the outer gill are attached to the body in such a way that their proximal portions make up the inner lamella of the outer gill.

2. At the bottom or free edge of the gill each tentacle bends outwards and upwards upon itself, so that its distal half lies parallel to and near its proximal half. The distal portions of the tentacles make up the outer lamella of the outer gill.

3. The gill tentacles of the inner gill are bent upon each

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other, but in the opposite direction, and the proximal halves of the tentacles here form the outer lamella, and the distal halves the inner lamella.

4. The points of attachment of the gill tentacles to each other.

(i.) All the tentacles of a gill are attached to each other, and to the body along the line *i*.

(ii.) The distal ends of the tentacles are united to form the ridge (*k*) which forms the dorsal margin of the outer lamella of the inner gill, and of the inner lamella of the outer gill.

(iii.) Each tentacle is very slightly united to the adjacent tentacles by junctions which give way to the slightest strain, and which are represented diagrammatically by the dots upon the right half of Fig. 150. These points of union may be termed the *inter-tentacular junctions.*

(iv.) Upon attempting to straighten a tentacle, the two halves will be found to be fastened together by bands which run from the inner to the outer lamella. These bands, which may be called the *inter-lamellar junctions* (Fig. 150, *e*), are formed by the meeting and fusion of the walls of the two halves of the tentacle, which cannot be separated without rupturing the connecting band.

(v.) Each tentacle is hollow, and its cavity (Fig. 150, *f*), communicates with the longitudinal blood-vessels (*k*). At the points of inter-lamellar junction, the cavity of the descending portion of the tentacle communicates with that of the ascending portion, as shown in the left side of Fig. 150.

The resemblance between the embryonic gill of Cyclas and that of the adult Mytilus will be readily perceived. In each the gill is made up of a row of parallel tentacles,

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attached by their proximal ends to the body wall. Mytilus differs from the Cyclas embryo in having the tentacles bent upon themselves, so that their distal and proximal halves are parallel, and side by side, and the two extremities near each other. Mytilus also differs from Cyclas in having the distal ends of the tentacles united to each other, as well as by the union of the halves of the tentacle, through inter-lamellar junctions, and also by the slight adherence of adjacent tentacles by the inter-tentacular junctions.

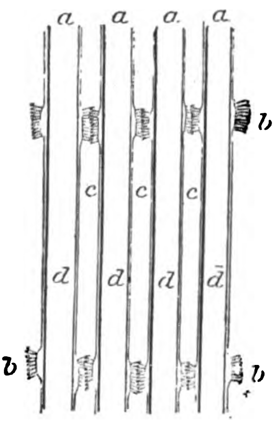

FIG. 151.

FIG. 151. — Surface view of four gill-tentacles of Mytilus edulis, magnified one hundred and fifty diameters. (Drawn from nature by W. K. Brooks.)

a, a, a, a. Gill tentacles. *b, b, b, b.* Inter-tentacular junctions. *c, c, c.* Inter-tentacular spaces. *d, d, d, d.* Cavities of tentacles.

c. Cut out a small piece of the unbroken gill of Mytilus, and mount it in glycerine or balsam, in order to examine its surface with a low power; note: —

1. The gill tentacles, running side by side from the dorsal margin to the ventral.

2. A series of lines at right angles to the tentacles, and much farther apart, the lines of inter-tentacular junction.

3. With a higher power, notice the cavities of the tentacles (Fig. 151, *a, a, a, a*), and the inter-tentacular spaces (*c, c, c*).

4. Notice that the wall of the tentacle becomes thickened at intervals (*b, b, b, b*), thus giving rise to projecting pads upon the sides of the tentacle.

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5. These pads are covered with large cilia which are hooked at their free ends, and the hooks upon the pads of adjacent tentacles interlock, thus forming the inter-tentacular junctions.

6. Since the ciliated junctions of the opposite sides of the tentacle are opposite each other, a line of junction extends along the surface of the gill, at right angles to the tentacles, and the surface of the gill is thus made up of a rectangular grating, the vertical sides of the openings being formed by the tentacles, and the horizontal ends by the junctions.

7. The spaces thus bounded (*c*, *c*, *c*) are the *incurrent ostia*, through which water passes into the space between the lamellæ.

8. Draw the tentacles, as seen in a surface view.

d. Embed a portion of a gill which has been hardened in chromic acid, and cut out and mount a number of transverse sections. Examine these with a high power.

1. Examine a section which has passed through the free portion of the tentacles, that is the portion which is not attached to adjacent tentacles either by inter-tentacular or inter-lamellar junctions.

(i.) The tentacle, when thus seen in section, is shaped somewhat like the sole of a human foot (Fig. 152, *a′*, *a′*) and consists of a central cavity (*e*) and a wall of epithelium.

(*a.*) The layer of epithelium is thin over the sides and inner surface of the tentacle, but the free end, that which forms the outer surface of the lamella, is covered with a thick layer of large cells.

(*b.*) These cells carry four bunches of large cilia (*d*, *d*) which project over the space (*c*) between the tentacles, and in the living animal cause the branchial currents in the water which bathes the gills.

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(*c*.) The cavity of the tentacle is lined by a chitinous sheath (*f*).

(*d*.) Within this sheath the cavity is irregularly divided by branching processes of connective tissue, within which a granular white blood-corpuscle may occasionally be found.

2. Make a drawing showing these points.

3. Examine a section which has passed through the inter-tentacular, but not through the inter-lamellar junctions (Fig. 152, *a*, *a*).

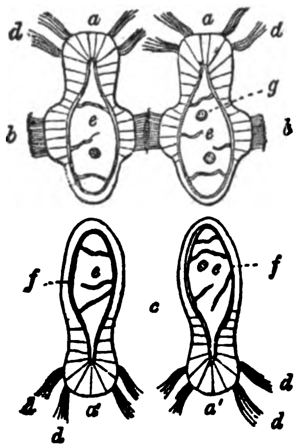

FIG. 152.

FIG. 152. — Transverse section of four gill-tentacles of Mytilus, as seen in a transverse section of the two lamellæ of a gill-plate. The section cuts two tentacles of one lamella (the upper in the figure) through the area of the tentacular junctions; the lower tentacles are cut between the tentacular junctions. (From "*The Minute Structure of the Gills of Lamellibranch Mollusca,*" by R. Holman Peck. Quar. Jour. Mic. Science, LXV., Jan. 1875.)

a, *a*. Sections through the inter-tentacular junctions of two tentacles of the outer lamella. *a'*, *a'*. Sections of two tentacles of the inner gill, between the inter-tentacular junctions. *b*, *b*. The bent cilia of the inter-tentacular junctions. *c*. Space between the tentacles. *d*. Tufts of cilia upon the outer edges of the tentacles. *e*, *e*, *e*, *e*. Cavities of the tentacles. *f*, *f*. Chitinous lining of this cavity. *g*. Blood-corpuscles within this cavity.

(i.) Notice the cavity, the chitinous sheath, the external epithelium, and the tufts of cilia, as in the preceding section.

(ii.) Notice also two pads (*b*, *b*) upon the sides of the tentacle, formed by the thickening of the epithelium, and carrying large hooked cilia.

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(iii.) Notice that the hooks of adjacent tentacles interlock to form the inter-tentacular junctions.

(iv.) Draw the section.

4. Examine a section which has cut the inter-lamellar junctions. (Fig. 153.)

(i.) Notice that the inner ends of the outer and inner halves of each tentacle are united (Fig. 153, *h*), and the cavities (*e*, *e*) of the two sides are continuous across the neck (*i*), thus formed.

(ii.) The chitinous linings of the two divisions of the tentacle line only the outer ends of this cavity (*f*), and do not extend into the central portion.

(iii.) Draw the section.

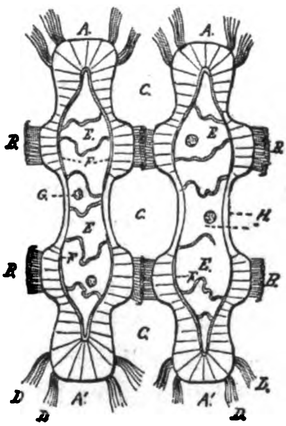

FIG. 153.

FIG. 153. — Transverse section of four gill-tentacles of Mytilus, through the inter-tentacular and inter-lamellar junctions. (From Peck.)

A, *B*, *C*, *D*, *E*, *F*, and *G*. as before. *H*. Inter-lamellar junction. *I*. Cavity of the inter-lamellar junction, continuous with the tentacular cavity *E*.

III. The *Gill of Unio*.

Remove the gills from one side of the body by cutting their attachments to the mantle and body; place them in water for examination. Each of the four gills is now seen to be a flat plate, with a nearly straight dorsal margin by which it is attached to the body, and a slightly curved ventral margin, which is free.

a. Examine the dorsal margin of one of the gills, and note that it is made up of two parallel plates, the two lamellæ, which are united at intervals by cross partitions, the inter-lamellar junctions.

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b. Introduce a small tube into the space between two of these partitions, and force air or water into the cavity. Notice that this fills a narrow space, which runs from the dorsal to the ventral margin, where it ends blindly. The air does not escape laterally, thus proving that the inter-lamellar partitions reach from top to bottom of the gill, and divide its cavity into a number of parallel vertical chambers, the *water tubes*, which are closed below, open above, and separated from each other.

c. On the side or face of the gill notice the fine parallel lines, which run from the dorsal to the ventral edge. These are the gill tentacles.

d. Notice also a second set of vertical lines, much farther apart than the finer lines; these indicate the edges of the inter-lamellar partitions.

e. Cut out a small piece of the gill; place it on a glass slide; cover it with water, and with a pair of fine forceps tear away the lamella which is uppermost, and thus expose the inner surface. Wash the portion which remains upon the slide, and then stretch it thoroughly with needles, and examine it with a low magnifying power (fifty to one hundred diameters).

1. In a surface view notice the parallel, brown, torn edges of the inter-lamellar partitions, and between them the more transparent spaces of the water tubes.

2. Select a part of the specimen where the partitions are somewhat widely separated, and focus a little deeper, thus bringing the inner surface of the wall of the water tube into view. Notice the irregular, scattered, somewhat oval openings, the inner ends of the inhalent ostia, through which the water gains access to the cavity of the water tube.

3. Focus still deeper, so as to bring the external surface

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into view. Notice the dark lines, more numerous than, but parallel to, the partitions. These are the gill tentacles.

(i.) Crossing these at right angles, and two or three times as far apart, a number of parallel, brownish, granular lines, the inter-tentacular junctions.

(ii.) In each of the meshes of the rectangular grating which is formed by the intersection of these two sets of lines, notice a rectangular aperture with rounded ends, the external opening of the inhalent ostium.

(iii.) Note, by focusing up and down, that each of these is continuous with one of the irregular openings already noticed.

f. Make sketches showing these points.

g. Turn the specimen over to examine its external surface; wash and stretch it as before, and examine it with a low power.

1. Notice the fine parallel vertical lines, the edges of the gill tentacles.

2. Between the tentacles are vertical channels or gutters, each of which is covered by two rows of large and very active cilia, which project from the edges of the tentacles, and meet over the grooves.

3. Place a little finely divided carmine upon the specimen, and notice the ciliary currents along the furrows.

h. Wash the specimen; gently cover it with a glass cover, and examine it with a high power.

1. Focus so as to bring the outer surface into view. and notice the rows of cilia along the edges of the tentacles.

2. Focus a little deeper, and notice the double row of chitinous rods inside each tentacle.

3. Running across the spaces between the tentacles are the fibrous inter-tentacular junctions.

4. Between the tentacles are the apertures of the inhalent ostia, situated at the bottoms of the furrows.

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5. Focusing a little deeper, notice that each tentacle is a tube, with a cavity which is irregularly divided by connective tissue fibres, among which white blood-corpuscles may occasionally be found.

4. In order to gain a clear conception of the relations of the parts of the gill, it is necessary to study sections of hardened specimens. The more important points are readily shown in sections of gills which have been placed, for twelve hours, in a three-tenths of one per cent solution of chromic acid; and the hardened gills may be preserved in ninety per cent alcohol.

a. Examine a transverse section, that is, one across the water tubes, with a low power. Note: —

1. The two lamellæ (*B* and *C*, Fig. 154), bound together at intervals by the inter-lamellar partitions (*E*, *E*, *E*).

2. The water tubes (*A*, *A*, *A*).

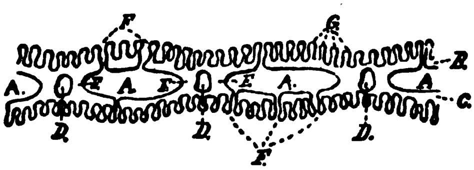

FIG. 154.

FIG. 154.— Transverse section of the gill of Unio purpurea, magnified eighty diameters. (Drawn from nature by W. K. Brooks.)

A, *A*. Water-tubes. *B*. Outer lamella. *C*. Inner lamella. *D*. Blood-vessels. *E*. Inter-lamellar partitions. *F*. Inhalent ostia. *g*. Gill-tentacles.

3. In some of the partitions, the cut sections of blood-vessels (*D*, *D*).

4. The outer surface of each lamella is seen to be folded or corrugated, thus forming a series of rounded prominences (*G*, *G*, *G*), the sections of the gill-tentacles.

5. Between these tentacles are the furrows, which vary

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in depth, some being quite shallow, while others (*F*, *F*), open into the water cavity.

b. Make a sketch of the section.

c. Examine a portion of the section with a higher power, two hundred and fifty diameters, noticing: —

1. The nearly oval cross sections of the external margins of the gill tentacles (Fig. 155, *g*, *g*, *g*.)

2. The narrow necks by which these are joined to the body of the lamella (*r*).

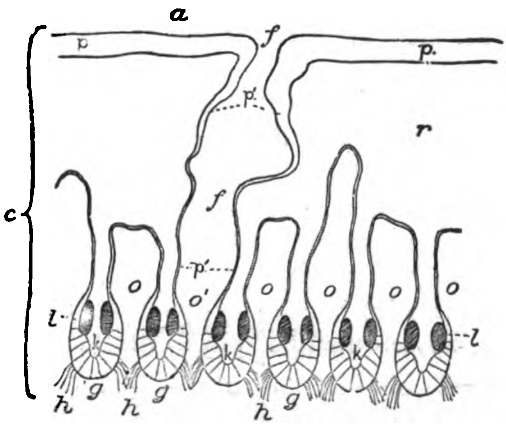

FIG. 155.

FIG. 155. — Transverse section of a portion of the gill of Unio purpurea, magnified two hundred and fifty diameters. (Drawn from nature by W. K. Brooks.)

a. Inter-lamellar water-tube. *c.* Outer lamella. *f.* Inhalent ostium. *g.* Gill-tentacles. *h.* Their cilia. *k.* Their cavities. *l.* Chitinous rods. *o.* Inter-tentacular furrows. *p.* Epithelial lining of water-tube. *p'.* Epithelial lining of inhalent ostium. *r.* Lamella.

3. The cross sections of the channels (*o*, *o*, *o*) between the tentacles.

4. Some of these channels will be found to penetrate the whole thickness of the lamella, as at *f*, thus opening into the water tube (*a*).

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5. Notice that the layer of epithelium which lines the water tube (p) may be traced outwards at (p') until it becomes continuous with that which covers the exposed edges of the tentacles.

6. The epithelium of the tentacles is greatly thickened, and is made up of a single layer of large cells, which carry the cilia (h, h) which project over the channels between the tentacles.

7. Behind this thickened epithelium is the somewhat triangular cavity of the tentacle (k).

8. On the sides of this cavity are the cross sections of the chitinous rods (l).

9. Back of these rods is the narrow neck connecting the tentacle with the body of the lamella.

10. The cavity of this neck is traversed in different directions by scattered irregular connective tissue fibres, not shown in the diagram, between which blood-corpuscles will occasionally be found.

11. The space (r) is occupied by a network of branched connective tissue, through which the blood finds its way.

d. Make a drawing of the section, showing all these points.

(iv.) A comparison of the gills of the Cyclas embryo, of Mytilus, and of Unio, shows that in all of them the gills are made up of a series of parallel tentacles, bent upon themselves to form the two lamellæ, and that the inter-lamellar and inter-tentacular junctions, which are slight in Mytilus, are in Unio so much developed as to bind the tentacles into a continuous organ.

The gill partitions of Unio are thus seen to be homologous with the inter-lamellar junctions of the two halves of a tentacle of Mytilus. The adjacent tentacles of Unio,

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instead of being loosely attached to each other at intervals, as in the inter-tentacular junctions of Mytilus, are fused together to form a continuous lamella.

XXVIII. THE DEVELOPMENT OF LAMELLIBRANCHS.

Among the Unionidæ the spawning season is very short, and the early changes of the egg take place so rapidly that it is rather difficult to find them for study; and as the later stages in the fresh-water forms are very aberrant, it is best for the beginner to study one of the more typical salt-water forms. The spawning season is short with them also, but it comes at different times in different species, and the examination of a number of forms will usually result in the discovery of sexually mature specimens of some species at almost any time during the summer months. When the reproductive elements are ripe, or nearly so, the abdomen is more or less distended by the reproductive organs, and the student can therefore judge what form to select for experiment. The method of artificial fertilization, which is described in Section XIV., is to be employed, but it is much more difficult to obtain perfectly ripe reproductive elements than it is with the sea-urchin; and the student should not be discouraged by repeated failures.

I. The *Fertilization of the Eggs.*

Having obtained and opened a number of specimens of a species which seems favorable, examine the contents of the reproductive organs in the following manner, in order to find the most perfectly ripe individuals.

If the point of a knife be pushed into the reproductive organ a milk-like fluid will ooze out of the cut, and a little

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of it may be taken upon a knife-blade and transferred to a glass slide for examination. The drop of fluid should be thoroughly mixed with a drop of sea-water and placed on the slide, and gently covered with a cover-glass, and examined with a magnifying power of about one hundred diameters. If the specimen is a female, this power will show that the fluid is almost entirely made up of irregular pear-shaped ovarian eggs (Fig. 156), each of which contains a large circular transparent germinative vesicle surrounded by a layer of granular slightly opaque yolk. It is almost impossible to describe the slight differences which distinguish the perfectly ripe egg from those which are nearly ripe but not capable of fertilization; although a very little experience will enable one to tell whether it is worth while to attempt the fertilization of the eggs of any given female.

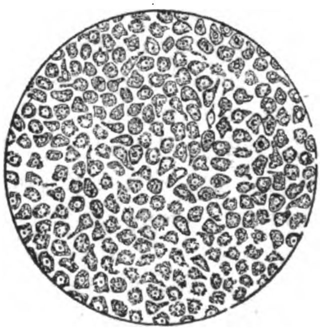

FIG. 156.

FIG. 156–172. — The embryology of the oyster. (All the figures were drawn from nature by W. K. Brooks, and unless the contrary is stated they are magnified two hundred and fifty diameters.)

FIG. 156. — Eggs from the ovary of a ripe female, magnified one hundred diameters.

When the drop of fluid is thoroughly mixed with the sea-water, the eggs should appear clean, sharply defined, separate from each other, and pretty uniformly distributed through the drop, as shown in the figure. If they adhere to each other, or if their outlines are indistinct, or if there is much fine granular matter scattered between the eggs, it is probable that the attempt at artificial fertilization will at best be only partially successful.

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When a perfectly ripe female is found, it should be set aside and the search continued for a male. When a drop of the milky fluid from a ripe male is mixed with a little sea-water and examined with a magnifying power of one hundred diameters, it is seen at a glance to be quite different from the fluid of a female. There are no large bodies like the eggs, but the fluid is filled with innumerable numbers of minute granules (Fig. 157), which are so small that they are barely visible when magnified one hundred diameters. They are not uniformly distributed, but are much more numerous at some points than at others, and for this reason the fluid has a cloudy or curdled appearance. By selecting a place where the granules are few and pretty well scattered, very careful watching will show that each of them has a lively dancing motion, and examination with a power of five hundred diameters will show that each of them is tadpole-shaped (Fig. 158), and consists of a small, oval, sharply defined "head" and a long, delicate "tail," by the lashing of which the dancing is produced.

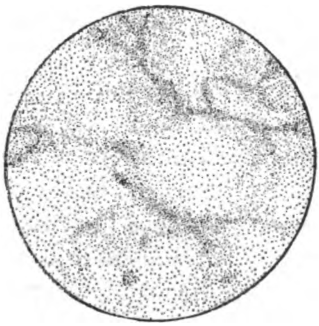

FIG. 157.

FIG. 157. — Ripe seminal fluid, magnified one hundred diameters.

It is more difficult to decide whether the male cells are perfectly ripe than it is to decide in the case of the eggs. With a magnifying power of five hundred diameters, each "head" should have a clear, well-marked outline, and they should be very uniform in size and separated from each other, as in Fig. 158. Under very favorable circum-

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stances this power should also show the "tails," as very faint undulating lines.

If the "heads" vary much in size, or if they are aggregated into bunches, with the "tails" radiating from the bunches in all directions, or if there is much granular matter so small that the outlines of the particles are not visible when magnified five hundred diameters, the fluid is not perfectly ripe, and fertilization with it will not, in all probability, be very successful.

FIG. 158.

FIG. 158. — A portion of Fig. 157 magnified five hundred diameters.

As the male cells are infinitely more numerous than the eggs, the ripe fluid from even one small male is enough to fertilize all the eggs of five or six large females.

In order to fertilize the eggs, all that is necessary is the mixture of the ripe eggs with a little of the ripe male fluid in a drop of water. If the point of a knife-blade be dipped in the fluid from a female and touched to a glass slide, and then dipped into the fluid of a male and touched to the same part of the slide, and a drop of sea-water be added, to cause the two to meet, most of the eggs will be fertilized, and their early stages of development can be studied in a single drop of water, but to secure the fertilization and healthy development of great numbers of eggs, several precautions must be observed, and a few instruments and pieces of apparatus are needed.

The following is a list of the things needed for procuring, fertilizing and hatching the eggs: A pair of sharp-pointed scissors; a pair of small forceps; half a dozen watch-crystals; a set of about half a dozen glass beakers, or tumblers, of different sizes, from half a pint up to half

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a gallon; two or three dipping-tubes, or glass tubes six or eight inches long, open at both ends, but with one end drawn out to a fine point; a small glass or rubber siphon for drawing the water out of the beakers. For tracing the development of the eggs, a microscope, magnifying at least one hundred diameters, and half a dozen glass slides and thin glass covers are wanted.

After the specimens have been opened, and at least one ripe male and one ripe female found, cut off the mantle lobes and gills of the male with the scissors, close to the visceral mass, and tear them out with the forceps and throw them away. Cut around the adductor muscle with the scissors, so that the visceral mass may be lifted out of the shell and transferred to a small saucer or to a watch-crystal. Holding the visceral mass with the forceps, cut out with the scissors as much as possible of the digestive organs and liver, and throw them away, and then chop up the reproductive organs with the scissors, picking out and throwing away any fragments of the liver, digestive organs, mantle or gills which may present themselves. In order to have the young thrive, the water must be kept free from fragments of the various organs of the adult, as these would soon decay and destroy the embryos, and it is therefore important to remove them as completely as possible. After the mass has been chopped up as fine as possible, fill up the watch-crystal with fresh sea-water, stir it up, and then allow it to run into one of the smallest beakers, which has been nearly filled with sea-water. As the water runs out of the watch-crystal, be careful to allow as few of the fragments as possible to run with it.

Now fill up the watch-crystal with water again, and stir and pour off as before, and repeat the process until nearly all of the male fluid has been washed out of the fragments

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and poured into the beaker. Stir the contents of the beaker for a short time, and then allow it to stand about five minutes, to allow any fragments to settle to the bottom, then pour the fluid, which should be quite milky, into another small beaker, leaving behind, to be thrown away, any particles which may have settled to the bottom. The male cells retain their full vitality for several hours after they have been mixed with sea-water, so the beaker may be set aside to wait until the eggs are ready. The eggs swell up and break to pieces within a very few minutes after they are mixed with water, unless they are fertilized at once, so it is much better to add the eggs to a previously prepared mixture of male cells and water than it is to put the eggs into the water to wait until the male fluid is got ready.

Taking now one of the females, remove and chop up the ovary in the same way in another watch-crystal, observing the same precautions in removing all portions of the body. Fill the watch-glass with water, and stir and pour off into the beaker as before, giving the contents of the beaker a good stirring after each lot of eggs is added, in order to diffuse them through the water at once, and thus ensure the speedy contact of each of them with some of the male cells.

Fill the crystal with water again, and stir and pour off, and repeat until all the eggs have been washed out of the fragments of the ovary.

Another female may now be cut up, and the eggs may be added to the contents of the same beaker, but if the females are large, and yield many eggs, it is not best to use more than one, for although there are enough male cells to fertilize a very great number of eggs, the eggs are heavier than water and soon sink to the bottom, and if

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they form a very thick layer, only those which lie near the surface have room to develop.

The beaker should now be allowed to stand for about ten minutes, and in the meantime some of the eggs may be picked out with a dipping-tube for examination under the microscope. In using the dipping-tube, cover the large end with the tip of the finger, and run the small end down close to the bottom of the beaker, and then take the finger off the top, and as the water runs in at the bottom it will carry some of the eggs with it. When the tube is filled, place the finger on the top again, and draw it out of the water, and, holding it perpendicularly on the centre of a glass slide, and taking the finger off the top, allow a good-sized drop to run out into the slide.

If things are working properly, each egg should now have a number of male cells attached by their heads to its outer surface, with their tails radiating from it in all directions, as shown in Fig. 159, and covering it in such numbers that the lashing of their tails causes the egg to rotate and move through the water.

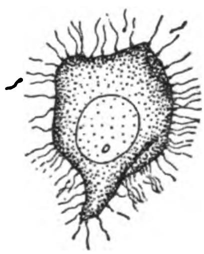

FIG. 159.

FIG. 159. — Egg about two minutes after fertilization; showing the irregular outline, the large germinative vesicle, and the spermatozoa, attached to the surface of the egg.

As soon as all the eggs have male cells attached to them, it is necessary to get rid of the superfluous male fluid, for it would soon decay and pollute the water if it were allowed to remain, and if it is not drawn off from the eggs while they are at the bottom, it is almost impossible to remove it after the embryos have begun to swim, without losing them as well.

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After a final stirring, the beaker should be allowed to stand for about five minutes, to allow the eggs to settle to the bottom, and the fluid above them should then be drawn off through a siphon, reaching nearly but not quite down to the eggs. A fresh supply of sea-water should then be added, and the eggs being stirred and allowed to settle, the water should be drawn off as before, and this should be repeated until the water, after the eggs have settled to the bottom, remains clear.

The beaker may now be set aside where it will not be exposed to sudden changes of temperature, and the eggs will require no further attention until the embryos begin to swim. The little embryos must of course be supplied with fresh sea-water from time to time during their development, and as they are so small that the water cannot be drawn off after they begin to swim, they must be supplied with fresh water by transferring them from time to time to larger and larger beakers. In two hours or so after the eggs are fertilized the embryos of the oyster begin to swim, and crowd to the surface of the water in great numbers, and form a thin stratum close to the surface. This layer of embryos may be carefully siphoned off into a very small beaker, and a little fresh sea-water added. In an hour or so there will be a new layer of embryos at the surface of beaker No. 1, and these should also be siphoned into No. 2, and this should be repeated as long as the embryos continue to rise to the surface of the first beaker. Every five or six hours a little fresh sea-water should be poured from a height of a foot or more into beaker No. 2, until it is filled. The contents should then be poured into a larger beaker, and sea-water should be added four or five times a day as before. In this way the embryos may be kept alive for a week, although they have by this time

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got into such a large vessel that it is almost impossible to find any of them for microscopic examination.

II. The *segmentation and development of the egg.*

The following description has been written from the eggs of the oyster, but it will be found to apply pretty exactly, except as regards time, to the developing eggs of other lamellibranchs.

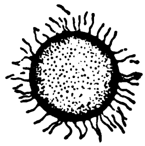

FIG. 160. — Egg about thirty minutes after fertilization.

FIG. 160.

About fifteen minutes after the eggs are fertilized, they will be found to be covered with male cells, as shown in Fig. 159. In about an hour the egg will be found to have changed its shape and appearance. It is now nearly spherical, as shown in Fig. 160, and the germinative vesicle is no longer visible. The male cells may or may not still be visible upon the outer surface. In a short time, a little transparent point makes its appearance on the surface of the egg, and increases in size, and soon forms a little projecting transparent knob, — the *polar globule*, or *direction cell*, — which is shown in Fig. 161, and in succeeding figures.

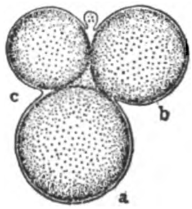

FIG. 161.

FIG. 161. — Egg two hours and eighteen minutes after fertilization; drawn with the formative pole of the principal axis at the top of the figure.

a. Macromere. *b.* Anterior micromere. *c.* Posterior micromere.

Recent investigations tend to show that while these changes are taking place, one of the male cells penetrates the protoplasm of the egg, and unites with the germina-

tive vesicle, which does not disappear, but divides into two parts, one of which is pushed out of the egg, and becomes the polar globule, while the other remains behind and becomes the *nucleus* of the developing egg, but changes its appearance so that it is no longer conspicuous. The egg now becomes pear-shaped, with the polar globule at the broad end of the pear, and this end soon divides into two parts, so that the egg (Fig. 161) is now made of one large mass and two slightly smaller ones, with the polar globule between them.

The later history of the egg shows that at this early stage the egg is not perfectly homogeneous, but that the protoplasm which is to give rise to certain organs of the body has separated from that which is to give rise to others.

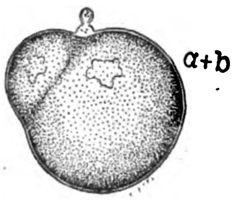

FIG. 162.

FIG. 162. — The same egg, ten minutes later, in the same position.
Letters as in Fig. 161.

If the egg in the stage shown in Fig. 161, were split in the plane of the paper, we should have what is to become one half of the body in one part and the other half in the other. The single spherule at the small end of the pear, the *macromere* (a), is to give rise to the cells of the digestive tract of the adult, and to those organs which are to be derived from it, while the two spherules at the small end, the micromeres (b and c), are to form the cells of the outer wall of the body and the organs which are derived from it, such as the gills, the lips and the mantle, and they are also to give rise to the shell. The upper portion of the egg in this and succeeding figures is to become the ventral surface of the adult oyster, and the surface which is on the

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right side in Fig. 161, is to become the anterior end of the body of the adult. The figure therefore shows the half of the egg which is to become the left half of the body. In most lamellibranchs, and especially in Unio and Anodonta, the micromere (*b*), is hardly distinguishable from the macromere (*a*), and the egg, at this stage, is like Fig. 162, instead of like Fig. 161.

In the oyster, this first stage of active segmentation is followed, as it is in the sea-urchin, by a period of rest, during which the divisions between the spherules (*a*, *b*, and *c*), become almost obliterated. In Unio and Anodonta, and in most marine lamellibranchs, the resting stages are hardly recognizable, and the egg passes almost immediately from one stage of segmentation to another, but in the oyster the resting stages are well marked. The oyster egg, in the first resting stage, is shown in Fig. 162. The macromere (*a*), and the anterior micromere (*b*), are so completely fused with each other that the line of separation is invisible, while that which separates the posterior micromere (*c*), from the rest of the egg is still distinguishable.

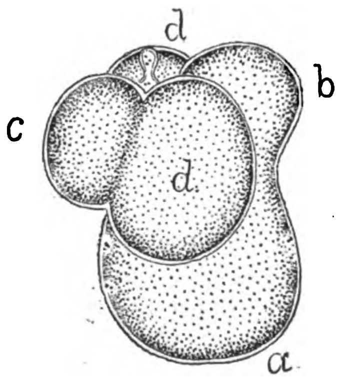

FIG. 163.

FIG. 163. — The same egg, ten minutes later.
a, *b*, and *c*. as in Fig. 161.
d, *d*. The new micromeres.

During the next stage of segmentation, the two micromeres (Fig. 163, *b* and *c*), again become sharply defined, and each of them divides into two, so that we now have one macromere (*a*), and four micromeres (*b*, *c*, *d*, *d*). In Unio,

Anodonta, and many marine lamellibranchs, the spherule (*b*), at this stage, is not constricted off from *a*. This period of activity is followed in the oyster by a second resting stage, and the micromeres then divide by repeated fusion into a cap of small *ectoderm* cells (Fig. 164, *ec*), which almost completely covers the macromere (*a*). At the same time the direction cell is carried towards the anterior end of the egg. Fig. 164 shows the oyster egg about six hours after fertilization.

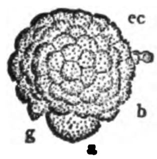

FIG. 164.

FIG. 164. — The same egg, seven hours and eight minutes later.
a. Macromere. *b*. Micromeres. *ec*. Ectoderm. *g*. Point where orifice of invagination is to be formed.

In about thirty hours after fertilization, the macromere of the oyster egg also begins to divide into smaller cells, and forms the digestive layer, or *endoderm*. In about thirty-six hours (Fig. 165), it becomes flattened, dorsally and ventrally; the endoderm (*en*), becomes pushed in on one of the flat sides to form a saucer-shaped digestive cavity with a wide mouth, the *orifice* of invagination (*g*); a *segmentation cavity* is visible between the endoderm, and the ectoderm (*ec*), and a few short cilia appear on the outer surface of the ectoderm. In from thirty-six to forty-eight hours, the oyster embryo assumes the form shown in Fig. 166. A tuft of cilia, the *velum* (*v*), is developed at the anterior end of the body, and the direction cell may frequently be seen among the bases of the cilia. The embryo now begins to swim actively, and finds its way to the surface of the water. An optical section (Fig. 167, *b*), will show that this embryo is the flattened embryo shown in Fig. 165, folded on itself, in such a way as to carry the endoderm (*en*), into the centre, and thus form a thick-walled

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digestive cavity, with a small opening (g). This is the *gastrula* stage, and a comparison with the sea-urchin will show that it is essentially like the sea-urchin gastrula, although it is not formed in precisely the same way. In the sea-urchin segmentation is total and perfectly regular, the segmentation cavity appears very early, and the endoderm cells are similar at first to the ectoderm cells, while in lamellibranchs, segmentation, although total, is irregular, the segmentation cavity does not appear until much later, and the micromeres, which are to form the ectoderm, are, from the first, quite different from the macromere, which is to form the endoderm.

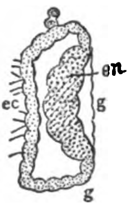

FIG. 165.

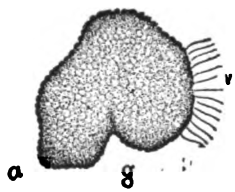

FIG. 166.

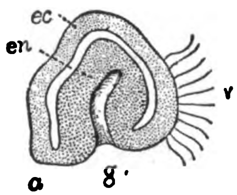

FIG. 167.

FIG. 165.—Embryo about thirty hours after fertilization, seen from the side in optical section.
ec. Ectoderm. *en*. Endoderm. *g*. Orifice of invagination. *sg*. Segmentation cavity.

FIG. 166.—Side view; and Fig. 167, Optical section of an embryo a few hours older, in the *gastrula* stage.
ec. Ectoderm. *en*. Endoderm. *v*. Velum. *g*. Orifice of invagination. *a*. Posterior dorsal angle of body.

In the sea-urchin the orifice of invagination becomes the anus of the pluteus, but in the oyster it soon closes up, and the anus is afterwards developed on the opposite side of the body.

The edges of the orifice of invagination of the oyster continue to approach each other, and finally meet and

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unite, thus closing up the opening, as shown in Fig. 168, and leaving the digestive tract without any communication with the outside of the body, and entirely surrounded by the outer layer. The embryos shown in Figs. 166 and 168, are represented with the dorsal surface below, but in Fig. 169, and most of the following figures, the dorsal surface is uppermost, for more ready comparison with the adult. The furrow in which the orifice of invagination was placed still persists, and soon a small, irregular plate (Fig. 168, *s*), makes its appearance at each end of it. These little plates are the two valves of the shell, and in the oyster they are separated from each other from the first, and make their appearance independently.

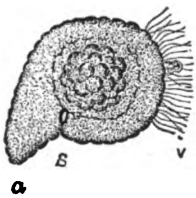

FIG. 168.

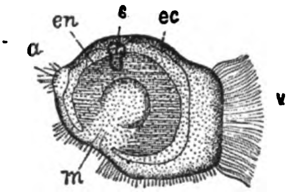

FIG. 169.

FIG. 168.—A somewhat older embryo, in the same position as Fig. 166.
s. Shell. *v*. Velum. *a*. Posterior dorsal angle of body.

FIG. 169.—A somewhat older embryo with the dorsal surface above.
m. Mouth. *ec*. Ectoderm. *en*. Endoderm.

Soon after they make their appearance, the embryos cease to crowd to the surface of the water, and sink to various depths, although they continue to swim actively in all directions, and may still be found occasionally, close to the surface. The region of the body which carries the cilia now becomes sharply defined, as a circular projecting pad, the *velum* (Fig. 168, *v*), and this is present, and is

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the organ of locomotion at a much later stage of development. It is shown at the right side of Fig. 169.

The two shells grow rapidly, and soon become quite regular in outline, as shown at *s*, in Figs. 169 and 172, but for some time they are much smaller than the body, which projects from between their edges around their whole circumference, except along a short area, the area of the hinge, upon the dorsal surface, where the two valves are in contact.

The two shells continue to grow at their edges, and soon become large enough to cover up and project a little beyond the surface of the body, as shown in Fig. 172, and at the same time muscular fibres make their appearance, and are so arranged that they can draw the edge of the body and the velum in between the edges of the shell. In this way that surface of the body which lines the shell becomes converted into the two lobes of the mantle, and between them a mantle cavity is formed, into which the velum can be drawn when the animal is at rest. While these changes have been going on over the outer surface of the body, other important internal modifications have taken place. We left the digestive tract at the stage shown in Fig. 168, without any communication with the exterior.

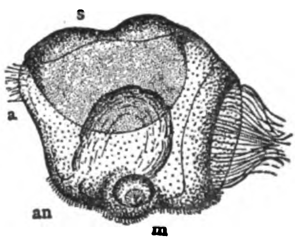

FIG. 170. — A still older embryo. *an*. Anus. *m*. Mouth. *s*. Shell.

FIG. 170.

Soon the outer wall of the body becomes pushed inwards, to form the true mouth, at a point (Fig. 169, *m*), which is upon the ventral surface, and almost directly opposite the point where the orifice of invagination was

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situated at an earlier stage. The digestive cavity now becomes greatly enlarged, and cilia make their appearance upon its walls, the mouth becomes connected with the chamber which is thus formed, and which becomes the stomach, and minute particles of food are drawn in by the cilia, and can now be seen inside the stomach, where the vibration of the cilia keeps them in constant motion. Up to this time the animal has developed without growing, and at the stage shown in Fig. 168 it is scarcely larger than the unfertilized egg, but it now begins to increase in size. The oyster reaches the stage shown in Fig. 172 in

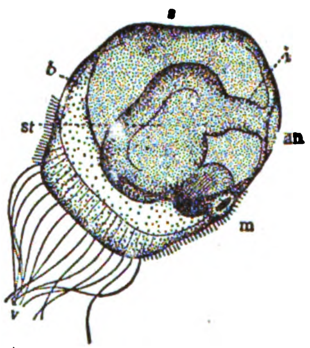

FIG. 171.

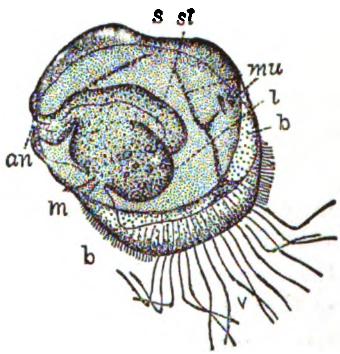

FIG. 172.

FIG. 171. — A still older embryo.
an. Anus. *a.* Posterior dorsal angle. *ma.* Mantle. *v.* Velum. *b.* Body cavity. *st.* Stomach. *i.* Intestine.

FIG. 172. — View of right side of an oyster embryo, six days old. *mu.* Muscles. *l.* Liver. *s.* Shell. Other letters as in Fig. 171.

from twenty-four hours to six days after the egg is fertilized; the rate of development being determined mainly by the temperature of the water.

Soon after the mantle has become connected with the stomach, this becomes united to the body wall at another

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point a little behind the mouth, and a second opening, the *anus* (Fig. 171 and 172, *an*), is formed. The tract which connects the anus with the stomach lengthens and forms the intestine, and, soon after, the sides of the stomach become folded off to form the two halves of the liver, as shown in Fig. 172.

Various muscular fibres now make their appearance within the body, and the animal assumes the form shown in Fig. 172.

III. The *Swimming Larva or Veliger.*

It is difficult to rear the embryos, but the later stages may be studied from specimens collected with the dip-net. The swimming larvæ or "Veligers" of marine lamellibranchs are so abundant at the surface of the ocean during the summer months that there is no difficulty in obtaining a supply. In order to find them, allow the material which has been collected with the dip-net or the tow-net (as described in Section VII.), to stand over night in a jar of sea-water. Then draw up with a dipping-tube a little of the sediment which has settled at the bottom, and placing it in a watch-crystal with a little sea-water, examine it with a magnifying power of about fifty diameters. A little searching will probably lead to the discovery of several of the larvæ lying upon the bottom among the sediment, tightly shut up in their transparent, orbicular, or kidney-shaped shells. The student will recognize them without difficulty, since the shell is shaped much like that of the adult. Having found a specimen, carefully note its position with reference to adjacent masses of sediment, and then try to rediscover it without a microscope. Having done so, push the sediment away from it with a hair, and sucking the specimen up into a dipping-tube, transfer it to a small quantity of fresh sea-water. Place it under the

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microscope, and allow it to remain undisturbed for ten or fifteen minutes. The soft parts of a tightly-closed specimen are so crowded together inside the shell that it is difficult to study them, and almost as soon as a specimen is fully expanded, it rises from the bottom and swims away by the motion of the cilia of the velum, but a little patience will probably lead to the discovery of half-expanded specimens, and these can be examined without much dif-

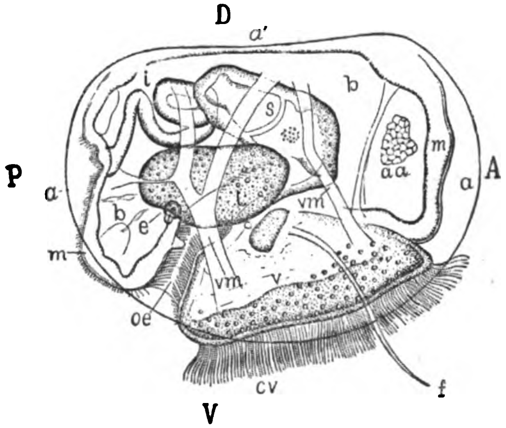

FIG. 173.

FIG. 173.—Right side of swimming larva, or *Veliger* of Montacuta ferruginosa, greatly magnified. (Copied with slight changes, from Lovén, "*Ent. der Mollusca Acephala Lamellibranchiata,*" Fig. 104.)

D. Dorsal surface. *V.* Ventral surface. *A.* Anterior end. *P.* Posterior end. *a.* Shell. *a'.* Hinge. *aa.* Anterior adductor muscle. *b.* Body cavity. *c.* Ear. *f.* Flagellum. *i.* Intestine. *l.* Liver. *m.* Mantle. *oe.* Œsophagus. *cv.* Cilia of velum. *v.* Velum. *vm.* Retractor muscles of velum.

ficulty. The larvæ will probably belong to several species, but most of those which are captured at the surface are sufficiently like Fig. 173 for the student to make this figure his guide in studying them.

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There is now a well-developed mantle chamber, into which all the soft parts are retracted while the animal is at rest. The *velum* (Fig. 173, *v*), is very large, and it fills the ventral half of the anterior end of the cavity between the shells, when retracted, but while the animal is swimming, the velum is protruded from between the valves. In most forms its outer surface is sunken, thus forming a conical basin, with a fringe of locomotor cilia, (*c, v*), around its rim. The depression in the centre allows the organ to be folded together when withdrawn into the shell, but when it is expanded, in swimming, it is nearly flat. In most forms, a long flagellum (*f*), arises from the bottom of the depression, and projects beyond the cilia. There are two large, flat muscles (*v, m*), on each side, to retract the velum.

The mouth, being behind the velum, is in the posterior half of the shell, and a long ciliated œsophagus (*oe*), runs upwards and forwards through the liver (*l*), to the stomach (*s*). A small tongue-like process from the posterior wall of the œsophagus, runs out into its cavity, just below the liver. The long, twisted intestine (*i*), is freely movable in the body cavity (*b*), and the anus is near the mouth. In most specimens, the auditory organs (*e*), can be seen a little posterior to the œsophagus, and there are usually two small pigmented eyes (not shown in the figure) carried upon short, blunt tentacles, at the base of the velum, anterior to the œsophagus.

The two renal organs, or organs of Bojanus, soon appear, as a pair of little tubular diverticula from the intestine, near the anus, and at about the same time the anterior adductor muscle (*a, a*), and, soon after, the posterior adductor, appears. The three pairs of ganglia appear before the commissures between them. The velum, ten-

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tacles and eyes disappear; the foot grows out between the mouth and anus, and the gills are developed as a row of ciliated tentacles on each side of the body. With the loss of the velum, the young animal usually settles to the bottom, although there are certain forms which are able to swim throughout life.

IV. The *larvæ of Anodonta.* The eggs of Anodonta implicata pass from the ovary into the gills during the latter weeks of October, and they develop very rapidly. The early stages are much like those of the oyster, as far as Fig. 169, except that the shell is not at first divided into two valves, but is continuous across the middle line. After this stage is reached, there is little resemblance between the young Anodonta and a marine larva. The shell and mantle develop very rapidly, while the digestive organs become rudimentary, and are not developed until five or six months later; in Anodonta implicata, not until the next summer.

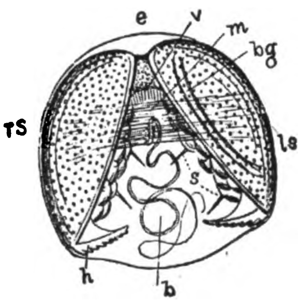

FIG. 174.

FIG. 174. — Anterior view of "Glochidium" larva of Anodonta, enclosed in the egg-shell; magnified about one hundred diameters. (Drawn from nature by W. K. Brooks.)

b. Byssus. *bg.* Byssus organ. *e.* Egg-shell. *h.* Hooks. *ls.* Left valve of shell. *m.* Posterior adductor muscle. *rs.* Right valve of shell. *s.* Setae. *v.* Velum.

If a female Anodonta be examined at any time between November 1st and April 1st the outer gills will be found distended by a brownish-red mass, which microscopic examination shows to be made up of the embryos, still enclosed in the egg-shells. One of them is shown from in front in Fig. 174, and in ventral view, after the removal

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of the egg-shell, in Fig. 175. The two valves of the shell are united by a hinge, and they are somewhat triangular in side view. The elasticity of the hinge ligament is so great that it may open the valves until they lie in the same plane. The ventral angle of each valve is bent inwards to form a movable toothed hook (Figs. 174 and 175, *h*), from which the larva has received its name "Glochidium."

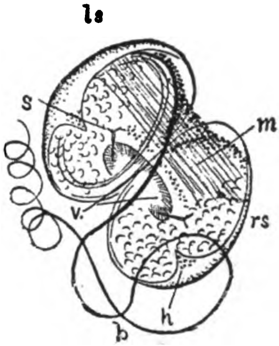

FIG. 175. — Ventral view of the same larva, with the valves of the shell opened. (Drawn from nature by W. K. Brooks.) Letters as in Fig. 174.

FIG. 175.

The valves are lined by the large spherical cells of the mantle, and from some of them large stout setae (*s*) project into the mantle cavity. The valves are closed by a very large and well-developed adductor muscle (*m*); but the elasticity of the hinge ligament is so great that repeated efforts are necessary before the animal can close the shell completely after it has been thrown open. The space between the halves of the mantle is usually almost entirely filled by a long, elastic, tough, brown, coiled thread, the *byssus*, which is shown at *b*. The byssus is formed in a long, tubular byssus organ (*bg*) which is coiled inside the left valve of the shell, between it and the cells of the mantle. The Glochidium has no ears or eyes, no gills, and there is no projecting locomotor velum, although a row of cilia (*v*), at the anterior end of the body, may be a rudimentary velum. The digestive cavity is not divided into regions, but is a simple pouch with

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thick walls and a single large opening, just under the letter *v* of Fig. 174. The embryo of Anodonta reaches this stage of development within a few days after the eggs are laid, and it remains almost without change until late in the following spring. The parent then discharges the larvæ through the cloacal siphon into the water, where they float for a short time. It is probable that all that settle to the bottom die. Others are entangled by their byssus threads to the tails, dorsal fins and gills of small fishes. These close the valves of the shell onto the body of the fish, driving the hooks into it. The setae probably excite inflammation in the skin of the fish. At any rate the epithelial cells of the skin grow at an unnatural rate, and soon build up a covering over the larva, which is thus enclosed in a brood-pouch, where it completes its development, acquires gills, an œsophagus, stomach, intestine, and renal organs and heart, and then escapes from the brood-pouch and falls to the bottom to complete its growth.

XXIX.—THE GENERAL ANATOMY OF THE SQUID.

(*Loligo Pealii.*)

With a little thought the student should be able to trace out the general anatomy of any Dibranchiate Cephalopod by the use of the following description, but as the various forms differ greatly, he should, if possible, study one of the squids. The description has been written from Loligo Pealii, but any species of Loligo or Ommastrephes will answer for laboratory work.

Specimens may be obtained by the dredge or trawl, but as they are frequently captured in great numbers by fish-

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ermen, in their nets, the best way to obtain a supply is by a visit to some fishing station upon the seashore.

If they are to be preserved in alcohol for dissection, they should be placed in about fifty per cent alcohol for a few hours, before they are transferred to strong alcohol, and the latter should be changed once or twice during the first three or four days.

I. *External Form.*

1. In an alcoholic or a fresh specimen notice: (*a*) the long cylindrical body; (*b*) the somewhat movable head, with its large eyes (Fig. 176, *d*), and with five pairs of tentacle-like arms (Fig. 176, *a′*, *a″*, *a‴*, *a⁗*, *b*); (*c*) the mouth situated in the centre of the space between the bases of the arms; (*d*) the tip of the brown, horny beak, which usually protrudes a little from the mouth; (*e*) the pair of large triangular fins, which are joined to the surface of that third of the body which is farthest from the head; (*f*) a crenated fold of membrane, the olfactory organ (Fig. 176, *f*), on each side of the head, behind the eyes.

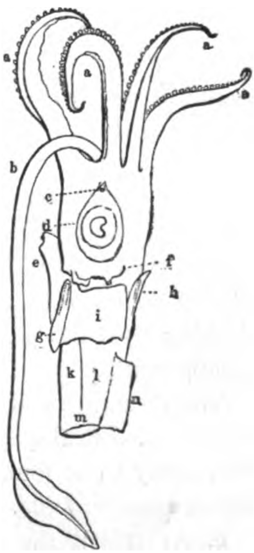

Fig. 176.

FIG. 176.—Side view of the head of Loligo Pealii. (Drawn from nature by W. K. Brooks.)

a. Dorsal arm. *a*ᶦᵛ. Ventral arm; the tip of this arm on the left side becomes modified in the male as the hectocotylus). *b*. Grasping arm. *c*. External opening of eye. *d*. Eye. *f*. Olfactory organ. *g*. Siphon cartilage. *h*. Neck cartilage. *i*. Lateral chamber of siphon. *e*. Ventral chamber of siphon. *k*. Retractor muscle of siphon. *l*. Retractor muscle of head.

For convenience in description we shall in the present paper speak of the end of the body, where the head is placed, as *anterior*, and the opposite pointed end as *posterior;* the surface to which the fins are attached we shall call *dorsal*, and the opposite surface *ventral*. The student must not infer, however, that these terms are of morphological value, or that the regions which they designate in the Squid are the same as the regions designated by similar terms in other Molluscs.

2. Place the animal with its dorsal surface uppermost, and notice: —

a. The long cylindrical body, ending posteriorly in the pointed, arrowhead-shaped fin.

b. The small dark-brown pigment spots, or chromatophores, which cover the surface of the body and head. Examine the chromatophores upon various parts of the body with a lens. In an alcoholic specimen most of them are flat, brown, oval, plate-like bodies, but some may be found in which the outline is irregular, and with radiating processes running out into the surrounding tissues. In a living animal the chromatophores are brightly colored, and are constantly undergoing changes of shape and size, expanding until the edges of adjacent ones almost come into contact, and then contracting to almost invisible spots. Owing to these changes, blushes of color are continually flashing over the surface of the body, and then suddenly disappearing.

The structure and changes of the chromatophore can be best studied in the small transparent embryos, which are frequently to be found at the surface of the ocean during the summer months.

c. Anteriorly the body proper ends in a free edge or collar, the margin of the *mantle*, which is separated from the head by an interspace, the *mantle chamber*.

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On the median dorsal line the mantle gives rise to a short flap, which projects forwards over the head.

d. Turn this flap over and slit the thin integument of its inner surface, and notice inside it the anterior end of the dark-brown, horny, internal shell, or *pen.*

e. Make an incision through the integument, along the median dorsal line, from the base of this flap to the posterior end of the body. Turn back the integument on each side of this incision, and notice the internal shell in its capsule.

(1.) Raise up one end of the shell and pull it out of the capsule, noticing that it is not attached to the walls in any way, but is entirely free.

(2.) The shell is thin, transparent, and horny, and consists (*a*) of a central shaft, which runs from end to end, like the quill of a feather, and which is strengthened by three parallel ridges, and (*b*) of two lateral portions, like the vanes of a feather, one on each side of the posterior five-sixths of the shaft, and strengthened by a marginal ridge.

(3.) Make a sketch of the shell.

(4.) Notice that the capsule of the shell is a closed sac, lined by a delicate membrane, and without communication either with the exterior or with the body cavity.

f. In a dorsal view of the head, notice the protruding eyes, and three pairs of arms (Fig. 176, *a*, *a′*, *a″*), which are visible in a dorsal view. Notice that these arms are symmetrically arranged with reference to the dorsal median line.

g. Make a sketch of the dorsal view of the animal.

3. In a ventral view notice: —

a. The delicate parallel bands of muscles which extend from the body to the lateral edges of the fin.

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b. Two tooth-like prolongations of the anterior edge of the mantle, behind the eyes.

c. The end of the *siphon* (Figs. 176, *e*, 177, *d*), projecting from the mantle chamber, on the median ventral line, bending towards the ventral surface, and ending in a transverse oval aperture (Fig. 177, *c*), which is furnished with a valvular fold.

d. In the ventral view of the head notice a pair of arms (Fig. 177, a^{iv}), one on each side of the median line.

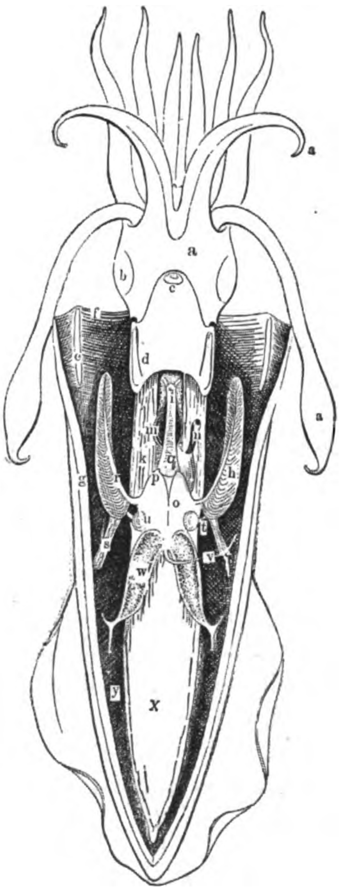

FIG. 177.

FIG. 177. — Male specimen of Loligo Pealii, with the mantle opened to show the body and gills. (Drawn from nature by W. K. Brooks.)

a. Head. a^{iv}. Ventral arm. a^{v}. Grasping arm. *b*. Eye. *c*. Siphon. *d*. Cartilages of siphon. *e*. Cartilages of mantle. *f*. Free edge of mantle. *g*. Mantle. *h*. Gills. *i*. Rectum. *k*. Retractor muscles of siphon. *m*. Ink bag. *n*. Penis. *q*. Intestine. *r*. Branchial veins. *s*. Gill muscles. *t*. Branchial artery. *u*. Branchial heart. *o*. Renal organs. *p*. Orifice of renal organ. *v*. Mantle artery. *w*. Posterior venæ cavæ. *x*. Visceral sac. *y*. Mantle cavity.

e. Outside the bases of these arms a pair of much longer ones, the grasping arms (Fig. 177, a^{v}), each of

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which consists of a long, slender, cylindrical shaft, terminating in a large rhomboidal expansion, upon which are four rows of cup-shaped suckers or *acetabula*, while the remaining eight arms have two rows each of acetabula.

f. Make a sketch of the ventral surface.

g. Examine the acetabula with a hand lens; notice: —

(1.) The short peduncle or stem.

(2.) The enlarged terminal cup, on the outer or flat surface of which notice: —

(*a*.) The membraneous marginal lip, which encircles the aperture.

(*b*.) Inside this a horny ring, with its outer or exposed edge serrated with fine teeth.

(*c*.) Within this a shallow cavity, at the bottom of which is a flat surface, the piston.

(*d*.) Cut a longitudinal section of one of the acetabula, and with a hand lens notice that the piston is made up of a mass of muscles, which are attached to the bottom of the cup, and so arranged as to pull back the piston, by which the sucking action of the acetabula is affected.

II. The *Mantle Chamber*.

Notice that while the anterior edge of the mantle is not attached to the head at any part of its circumference, it is in contact with it at three nearly equidistant points, on the median dorsal line and at the sides. Open the mantle cavity by an incision through the integument, from the anterior margin nearly to the posterior end, and a little to the left of the median line. Place the animal under water, and turn back the halves of the mantle, in order to expose its cavity. Notice that while the mantle cavity extends upon the sides and ventral surface, nearly to the posterior end of the body, it is quite shallow on the median dorsal line, and about an inch from its anterior margin the mantle is joined to the neck.

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a. On the dorsal surface of the neck notice the dorsal mantle cartilage (Figs. 176, *h*, 190, *l*), an elongated, flattened, cartilaginous plate, with a groove along the middle of its surface, and a ridge on each side of the groove.

b. Lying upon this plate, but covered by the integument of the mantle, notice the upper end of the pen (Fig. 190, *n*), with a longitudinal ridge which fits into the groove in the plate.

c. On each side of the body the edge of the mantle is produced forwards, forming a tooth-shaped point.

d. On the inner surface of the mantle, in the same region, is a longitudinal ridge (Figs. 177, *e*, 190, *i*), about an inch long.

e. On the outer edges of the base of the siphon are two *siphonal cartilages* (Figs. 176, *g*, 177, *d*, 190, *h*), each of which carries a longitudinal groove, into which the ridge on the inner face of the mantle fits.

f. The head is attached to the mantle by a neck, which is mainly composed of four large muscles, the two dorsal retractors of the head (Fig. 176, *l*), and the two ventral retractors of the siphon (Fig. 176, *k*).

g. On each side of the first pair of muscles, just posterior to the dorsal mantle cartilage, notice a pair of nerves which pass out from the neck into the mantle, and end in the large *ganglia stellata*, which supply the mantle with nerves.

h. The siphon is now seen to be somewhat pyramidal in shape, and wrapped around the neck, with the small end pointing forwards; its cavity is divided into three chambers.

1. The funnel-shaped ventral chamber (Fig. 176, *e*), communicating with the mantle cavity at its broad end, and with the small valvular external aperture at the small end.

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2. On each side of it is a lateral chamber (Fig. 176, *i*), open posteriorly but closed anteriorly, and entirely separated from the cavity of the ventral division.

It will be seen that when the walls of the mantle chamber contract to expel the contained water, any water which is driven into these lateral chambers will simply force their free posterior margins out against the mantle, thus forming a valve to prevent the water from passing out.

The only exit will then be through the ventral chamber; and during life, the stream of water which is thus driven through the ventral siphon at each respiration, is the principal means of locomotion.

The superficial appearance of the contents of the mantle chamber varies considerably, according to the sex of the specimen. When the mantle of a male specimen is laid open it presents the appearance shown in Fig. 177, but most of the structures shown in this figure are, in the female, covered up by the large, hemispherical, white, finely striated *nidamental glands*. When these are removed the parts under them are much like those of the male, but the student should, if possible, select a male specimen for studying the general anatomy.

i. In the male specimen, notice, in the middle line, just behind the siphon, the rectum (Fig. 177, *q*), which is bound down onto the other viscera by a mesenteric fold. At its anterior end notice the *anus* (*i*), guarded by a pair of ear-like valves. Dorsal to the intestine, but projecting beyond it so as to be visible on each side of it in a ventral view, notice the ink bag (Fig. 177, *m*).

j. Running forward from it on the inner surface of the intestine, notice the ink duct, which opens into the siphon, behind the tip of the rectum.

k. In the male, notice on the right side of the intestine

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the external opening of the reproductive organ, situated at the end of an elongated papilla (Fig. 177, *n*).

l. On each side of the intestine, about an inch behind the anus, a small papilla, the opening of the *renal organ* (Fig. 177, *p*).

m. Posterior to these orifices are the renal organs, a pair of transparent-walled pouches (Fig. 177, *o*), with an indefinitely marked outline, one on each side of the rectum; near the anterior ends of these organs, notice that the rectum bends downwards, and passes behind them.

n. Running out from behind each renal organ into the surface of the mantle is the *branchial* vein (Fig. 177, *r*), through which aerated blood is returned from the gills to the heart.

o. On each side of the body is a plumose gill (Fig. 177, *h*), which is free ventrally, but attached dorsally to the mantle. Notice that the branchial vein runs along its free ventral surface.

p. Just behind the point where the branchial vein passes below the renal organ, notice on each side of the body a small white oval body, the *branchial heart* (Fig. 177, *u*), covered by a delicate transparent pericardium.

1. Notice the *branchial artery* (Fig. 177, *t*), which passes from each branchial heart to the gill, and runs along the line upon which the dorsal surface of the gill is joined to the mantle.

q. On the median line, a little posterior to the branchial hearts, a large artery, the *median mantle artery* (Fig. 177, *v*), runs from the surface of the mantle chamber to the inner surface of the mantle, where it divides into an anterior and a posterior branch.

r. On each side of the point where this artery leaves the body, a large cone-shaped organ may usually be

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found, running backwards and downwards around the body into the mantle, where it divides into an anterior and a posterior branch, which pass into the muscular layer of the mantle. These bodies (Fig. 177, *w*) are made up of an artery and a vein, united in a common fold of mesentery, the *lateral mantle artery* and the *posterior vena cava*. In an alcoholic specimen the vein is usually greatly distended by coagulated blood.

s. Posterior to these arteries is the large *visceral sac* (Fig. 177, *x*), reaching to the posterior end of the body, and covered by a delicate, transparent mesenteric membrane, which is reflected out along the ventral mantle artery and along the back, into the inner face of the mantle.

t. Make a drawing, showing as many of these parts as possible.

III. The *Circulatory and Renal Organs*.

With a pair of fine-pointed scissors cut through the thin membrane of the two renal organs, by a transverse incision just behind their external openings; and placing the specimen under water, pull off, with a fine pair of forceps, the wall of the renal organs, thus exposing their cavities (Fig. 178, *g*). With a stream of water, or a fine brush, gently wash away the fine white granular substance, which, in an alcoholic specimen, usually fills the cavity, and notice the intestine (Fig. 178, *h*), which lies between the two chambers.

a. On each side of this, notice a large, white, glandular body, which almost entirely fills the cavity of the renal organ; this is the glandular portion of the *anterior vena cava* (Fig. 178, *i*).

The anterior ends of the venæ cavæ of the two sides of the body bend down under the intestine, where they unite to form one median trunk, which will be noticed later.

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Their posterior ends are flattened, and lie near the surface of the body. Notice that the cavity of the renal organ entirely surrounds the glandular portion of the blood-vessel.

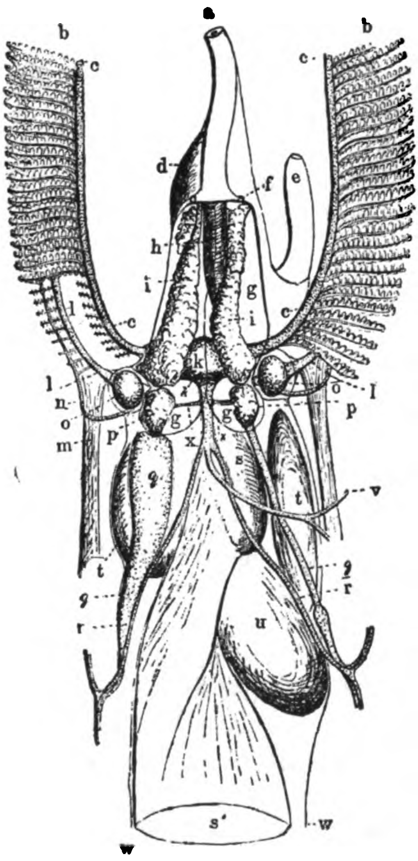

FIG. 178.

FIG. 178. — Superficial dissection of the renal and circulatory organs of male specimen of Loligo Pealii. (Drawn from nature by W. K. Brooks.) The capsules of the renal organs are opened, and the blood-vessels are freed from the adjacent organs.

***a*. Rectum, cut across. *b*. Gills. *c*. Branchial veins. *d*. Ink bag. *e*. Penis. *f*. Openings of renal organs. *g*. Cavity of renal organ. *h*. Intestine. *i*. Glandular portion of anterior vena cava. *k*. Systemic heart. *l*. Branchial artery. *m*. Gill muscle. *n*. Nutrient artery of gill. *o*. Branchial heart. *p*. Glandular portion of posterior vena cava. *q*. Enlarged portion of posterior vena cava. *r*. Lateral mantle artery. *s*. Stomach. *t*. Œsophageal end of stomach. *u*. Reproductive organs. *s'*. Blind sac of stomach. *w*. Capsule of abdominal viscera, or peritonæum. *x*. Artery to stomach and mantle.**

b. The anterior vena cava runs backwards as far as the branchial heart, where it unites with a much shorter glandular structure, the glandular portion of the *posterior*

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vena cava (Fig. 178, *p*), which is flattened, and nearly as wide as long.

c. Notice that the cavity of the renal organ (Fig. 178, *g*), extends backward only as far as the posterior end of this structure.

d. Following the posterior vena cava backwards, it will be found to be a thin-walled tube (Fig. 178, *q*), capable of great distension, and usually filled with coagulated blood. It runs back around the body into the mantle.

e. Carefully dissect away the membrane which covers it, and notice close beside it the *dorsal mantle artery* (Fig. 178, *r*).

f. Opposite and outside of the point where the anterior and posterior venæ cavæ meet, notice the branchial heart (Fig. 178, *o*), in a separate pericardial chamber.

g. Open this chamber and turn the heart over, and notice that the two venæ cavæ open into it, and that a large vessel, the *branchial artery* (Fig. 178, *l*), passes from it to the gill (*b*).

Trace this vessel out along the line where the gill is joined to the mantle, and notice that it gives rise, at right angles, to a series of small vessels, which pass into the gill leaflets, and there give rise to still smaller branches.

h. Dissect away the connective tissue which binds the ink bag and rectum to the surface of the body, until these organs can be turned to one side, as shown in Fig. 179, at *d* and *h*, to expose the structures below them.

1. Notice that the anterior vena cava of the left side gives off a small glandular branch to the intestine.

2. The two venæ cavæ (Fig. 179, *i*, *i*), then pass below the intestine, and unite to form a large flat glandular body, which lies upon the median line, and is contained in a prolongation of the renal organs.

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3. In the centre of this body the single, non-glandular, transparent, thin-walled *anterior vena cava* (Fig. 179, *10*), arises, and runs forward on the median line, through the siphon to the head.

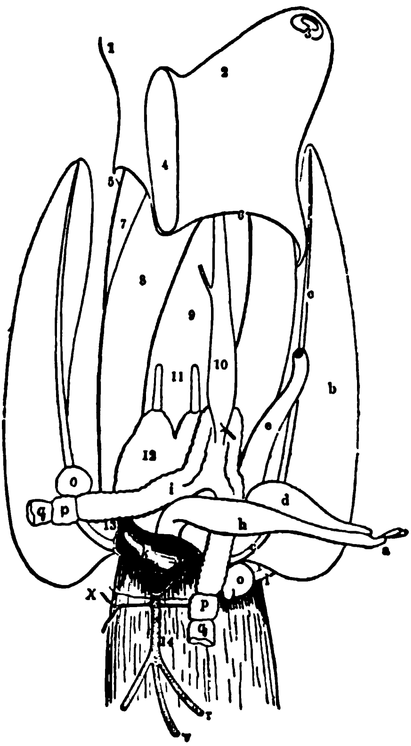

FIG. 179.

FIG. 179. — Deeper dissection of the circulatory organs of a male specimen of Loligo Pealii. (Drawn from nature by W. K. Brooks.) The posterior venæ cavæ (*q*, *q*) have been cut, and the right anterior vena cava has been turned to one side to show the systemic heart. The renal organs have been removed, and the intestine (*h*) and the ink bag (*d*) turned to the right, to expose the anterior vena cava, the liver (*9*), and the spleen (*12*).

The reference letters are the same as in Fig. 178. *1.* Head. *2.* Siphon. *3.* Valve in orifice of siphon. *4.* Siphonal cartilage. *5.* Lateral chamber of siphon. *6.* Median chamber of siphon. *7.* Retractor muscle of head. *8.* Retractor muscle of siphon. *9.* Liver. *10.* Anterior median vena cava. *11.* Hepatic ducts. *12.* Spleen. *13.* Anterior aorta. *14.* Posterior aorta.

4. Near the siphon it gives rise to a branch which passes towards the dorsal surface, and penetrates the soft white *liver* (Fig. 179, *9*), which lies between the large retractor muscles (Fig. 179, *7*, *8*,) of the head and siphon.

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5. Lift up the glandular vena cava of one side, and notice, near the point where it unites with its fellow, a glandular branch, which runs downwards into the substance of a white glandular body, the *spleen?* (Fig. 179, *12*), which lies below it.

i. The systemic heart and arteries.

Remove the branchial heart and venæ cavæ from the left side of the body, and notice below them, on the median line of the body, the smooth, white *systemic heart* (Figs. 178, *k*, 179, *k*), running obliquely across the body, with its anterior end to the left.

1. Near the middle of its posterior margin, the *posterior aorta* (Fig. 179, *14*), originates, and passes backwards on the median line.

2. This soon divides into three mantle arteries, already noticed (*v*, *v*, *v*).

3. Notice the *branchial vein* (Fig. 179, *c*, *c'*), which brings back the blood from the left gill, and opens upon the centre of the rounded left side of the systemic heart.

4. The *right branchial vein* opens into the pointed right side of the heart.

5. On the left side of the body, the anterior end of the heart gives rise to the *anterior aorta* (Fig. 179, *13*), which runs forwards to the left of and below the spleen. Its subsequent course will be traced in connection with the digestive organs.

IV. The *Digestive Organs*.

Remove both venæ cavæ; cut the anterior aorta, and remove the systemic heart, and carefully strip off the delicate membrane which covers the visceral mass.

a. The greater part of this mass is formed by a thin, delicate-walled pouch, the *blind sac* of the stomach (Figs. 178, *s'*, 180 and 181, *k*).

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b. At its anterior end this opens into the much smaller, muscular, thick-walled *stomach* (Figs. 178, *s*, 180 and 181, *h*, *i*).

c. At the anterior left corner of the stomach are the *œsophagus* (Figs. 180 and 181, *c*), and *intestine* (Figs. 180 and 181, *n*), side by side.

d. The intestine bends upwards between the two halves of the spleen (Figs. 180 and 181, *g*), and soon becomes constricted to form the rectum (Fig. 181, *o*).

FIG. 180.

FIG. 180. — Ventral view of the digestive organs of Loligo Pealii. (Drawn from nature by W. K. Brooks.)

Reference letters for Figs. 180 and 181: —

a. Nerves running to ganglia stellata. *b.* Liver. *c.* Œsophagus. *d.* Anterior aorta. *e.* Point where œsophagus and aorta pass out of liver on dorsal surface. *f.* Hepatic ducts. *g.* Spleen. *h.* Œsophageal chamber of stomach. *i.* Left side of stomach. *k.* Blind sac of stomach. *l.* Artery to testis. *m.* Testis. *n.* Intestine. *o.* Rectum. *p.* Anus. *q.* Ink bag. *r.* Ink duct. *s.* Anterior aorta. *t.* Systemic heart. *u.* Branchial veins. *v.* Posterior aorta.

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e. The œsophagus may be traced forwards on the left side of the body to a point just in front of the spleen, where it enters the liver (Figs. 180 and 181, *b*).

f. The anterior aorta (Fig. 180, *s*), will be seen to follow the same course, and to pass into the liver.

g. Carefully raise up the liver (Figs. 180 and 181, *b*), and notice that the œsophagus (Fig. 181, *c*) and aorta (Fig. 181, *d*) pass entirely through it, and run forwards on its lower surface to the head.

h. On the dorsal surface of the anterior end of the liver are a pair of small, compact, white glands, the *posterior salivary* glands, in contact with each other on the middle line. Their ducts pass into the head alongside the œsophagus, and they will be noticed in the description of the head. Running out from under them, notice

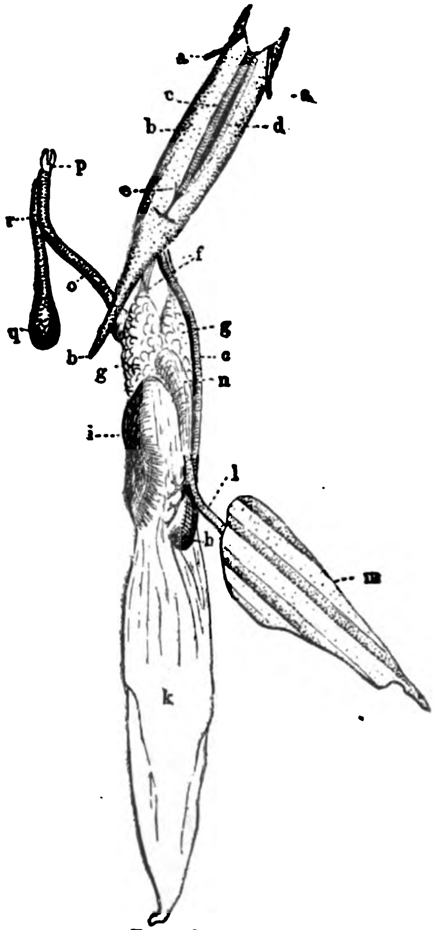

FIG. 181.

FIG. 181. — Dorsal view of the digestive organs of Loligo Pealli. (Drawn from nature by W. K. Brooks.)

For explanation of letters see Fig. 180.

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the nerves (Fig. 181, *a*, *a*), which pass to the ganglia stellata.

i. On each side of the œsophagus, where it passes into the ventral surface of the liver, is a delicate, transparent, *hepatic duct* (Fig. 180, *f*), which may be traced into the spleen (*g*), and through this organ to the stomach.

j. Raise up the stomach, and notice below it, in a capsule of its own, the testis or ovary, according to the sex of the specimen. A large, compact, white body on the median line, and on the left of it notice the accessory reproductive organs.

V. Divide the head vertically, with a razor, by a single cut through it, along the median line. In the section thus made notice:

a. The opening of the mouth, between the bases of the arms.

b. The two horny jaws, one on the dorsal side of the mouth, and one on the ventral side. The former (Fig. 185, *f*), is smaller than the ventral one, *d*, into which it shuts.

c. The nearly spherical, muscular, buccal body.

1. The cavity of the œsophagus (Fig. 185, c), running through it, near its dorsal surface.

2. The lingual ribbon (Fig. 185, *k*), lying upon the floor of the œsophagus.

d. Behind the buccal body the small œsophagus, (*c*), runs backwards through the head and neck to the body, where it lies dorsal to the liver, as already noticed.

e. In the section notice the cartilaginous ring or cranium which surrounds the œsophagus, in the posterior portion of the head.

f. The ganglia of the nervous system, which are arranged in a ring around the œsophagus, within and anterior to the cranium.

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VI. The *Reproductive Organs of the Male.*

a. Carefully examine the tip of the left ventral arm of a male specimen, — the arm which is marked a^{iv} in Fig. 177, and notice that the acetabula are absent, and that their stalks become modified into elongated papillæ, which are different in shape from the stalks of the acetabula on the other arms. Examine the tip of the corresponding arm of a female, and notice that it is not different from the tips of the other arms.

The portion of the left ventral arm of the male, which carries the papillæ, is a rudimentary *hectocotylus*, or copulating organ. It does not seem to be a reproductive organ in the squid, although it is fully developed and functional in many other Cephalopods.

b. The *Testis.* This is a somewhat flattened, pear-shaped gland (Figs. 180 and 181, *m*), which lies near the posterior end of the visceral mass, on its dorsal surface. It is enclosed in a thin, transparent, membraneous capsule, and the blind sac of the stomach is on its right side and ventral surface. Its upper surface is irregularly rounded; its lower end pointed; its ventral surface flattened and slightly concave, and its dorsal surface is convex, and marked by three or four parallel longitudinal ridges, which fit the longitudinal folds of the pen. Notice the genital artery (Fig. 181, *l*), which enters the testis on its upper edge, and helps to support it in its capsule. Notice also that a delicate membrane forms a sort of mesentery, which binds the testis to the dorsal wall of its capsule.

c. No duct is joined to the testis directly, and the ripe spermatozoa escape from the seminiferous tubules which open near the middle of the ventral surface, and pass into the cavity of the capsule, from which they pass into the *excretory duct.*

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This is a complicated mass of twisted and convoluted tubes, which is bound together, by connective tissue, into a compact body, which lies on the left of the testis. Its posterior end (Fig. 182, *h*) does not join the testis, but opens into its capsule, from which it receives the spermatozoa after they have escaped from the testis.

In order to examine the excretory duct, carefully separate the various folds, by dissecting away, under water, the connective tissue which binds them together. It will then be found to be divided into four regions, the *vas deferens*, the *vesicula seminalis*, the *prostate gland*, and the *spermatophoric receptacle*.

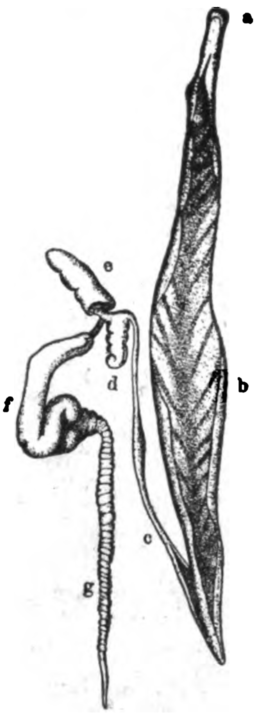

FIG. 182.

FIG. 182. — Male efferent duct of Loligo vulgaris. From Brock, "*Geschlechtsorgane der Cephalopoden.*" Z.Z. xxxii., 1, Taf. 1, Fig. 3.)

a. Penis. *b.* Spermatophore sac. *c.* Vas efferens. *d.* Blind sac of vas efferens. *e.* Prostate. *f.* Vesicula seminales. *g.* Vas deferens. *h.* End of vas deferens which opens into capsule of testis.

1. The *vas deferens* (Fig. 182, *g*), is a small, much convoluted tube, which opens, at its posterior end, into the left side of the capsule of the testis. Its distal end passes abruptly into the second region.

2. The *vesicula seminalis* (Fig. 182, *f*), is a much larger tube, which again may be divided into a proximal convoluted portion and an unfolded distal portion.

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3. The third division, or *vas efferens* (Fig. 182, *c*), is a long, straight, thin-walled tube, which passes backwards to open into the posterior end of the fourth division.

4. This is the *spermatophoric receptacle*. It is much larger and longer than any of the other regions, and it may again be divided into a distal portion or *penis* (Figs. 182, *a*, 177, *n*, 178, *c*, 179, *e*), with thick, muscular walls, and an enlarged proximal portion or spermatophoric pouch (Fig. 182, *b*), with thin transparent walls, inside which the long white thread-like spermatophores may usually be seen.

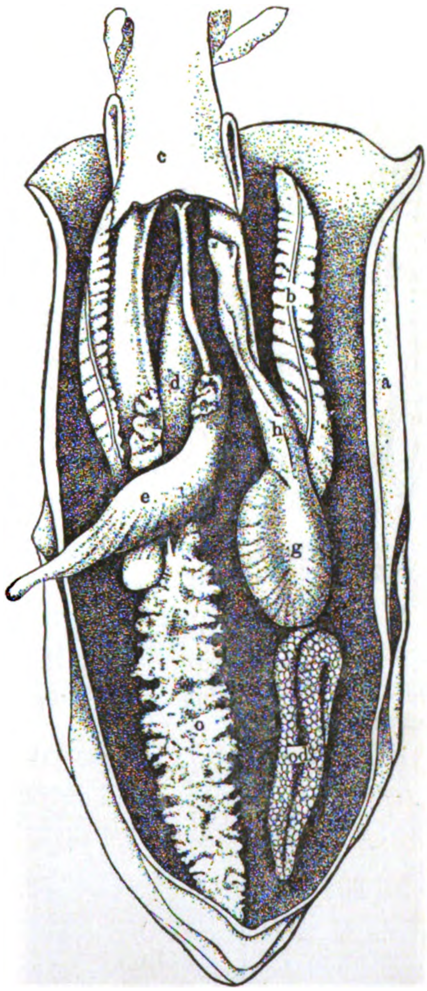

FIG. 183. — Female reproductive organs of Loligo vulgaris. (From Brock, Taf. 11, Fig. 20.) Drawn by S. Garman.

a. Mantle. *b*. Gills. *c*. Siphon. *d*. Ink bag. *e*. Blind sac of stomach, turned to one side. *g*. Gland of oviduct. *h*. Terminal portion of oviduct. *od*. Folded transparent portion of oviduct. *o*. Ovary.

FIG. 183.

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5. A small, compact, accessory gland, the *prostate* (Fig. 182, *e*,) opens into the vas efferens close to its proximal end, and near this is a blind pouch (*d*).

d. The *spermatophores*. The spermatophore of Loligo Pealii (Fig. 184) is a white, slender rod or thread, about half an inch long. When magnified it is seen to consist of three parts: an outer tubular sheath (*a*); a packet of spermatozoa (*b*), which fills nearly two-thirds of the sheath; and a long, complicated, discharging body (*c*), which is coiled up so as to form a long, elastic spiral spring.

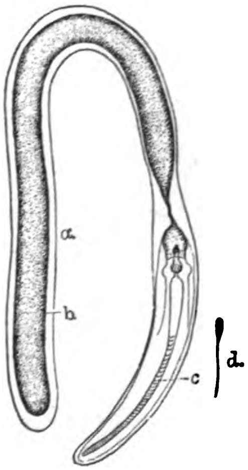

FIG. 184.

FIG. 184.—Spermatophore of Loligo Pealii, magnified about thirty diameters. (Drawn by W. K. Brooks from a sketch from nature by H. J. Rice.)

a. Sheath or capsule. *b*. Packet of spermatozoa. *c*. Discharging body. *d*. A single spermatozoon more magnified.

When a fresh spermatophore is placed in water, the sheath becomes ruptured at the end (*d*), and the discharging body springs out, dragging the packet of spermatozoa after it.

VII. The *Reproductive Organs of the Female*.

These are the *ovary*, the *oviduct*, the *gland* of the *oviduct*, the *nidamental glands*, and the *accessory nidamental glands*.

a. The nidamental glands. When the mantle of a female specimen is laid open, the region of the heart and renal organs will be found to be covered by a pair of large, white, rounded, laminated bodies, the *nidamental glands*,

which open at their anterior end into the mantle cavity. They excrete the capsules of the egg masses. In front of them, wrapped around the intestine and ink bag, are the much smaller accessory glands.

b. The ovary (Fig. 183, *o*) is situated, like the testes, in the dorsal portion of the posterior end of the visceral mass, and it is enclosed, like the testes, in a capsule, into which the eggs escape, to be taken up by the oviduct. The oviduct (Fig. 183, *o, d*) is a long, transparent, foliated tube, opening into the left side of the capsule of the ovary.

c. Near its anterior end the walls become thickened to form the gland of the oviduct (Fig. 183, *g*), and in front of this the oviduct runs forwards as a thick-walled tube (Fig. 183, *h*), which opens into the mantle cavity on the left side, near the base of the siphon.

VIII. The anatomy of the brain, the sense organs, and the buccal body, can be best studied in a series of transverse sections through the head, and very small specimens should, if possible, be selected, as the sections may then be made thin enough for microscopic examination.

During the summer, small squids, from half an inch to an inch and a half long, may frequently be found swimming at the surface of the ocean during the middle of the day, and they may be captured with a hand-net. They should be placed for three hours in a one-tenth per cent solution of chromic acid. They should then be placed for about six hours in a three-tenths per cent solution, and then, for the same time, in a one per cent solution. They may then be placed in seventy per cent alcohol, which should be changed in about twenty-four hours for eighty per cent. After they have been in this for about a day, they may be kept in eighty-five per cent or ninety

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per cent alcohol until they are wanted. They should then be placed in absolute alcohol for ten or twelve hours, after which they may be mounted in paraffine, as described in Section VII. A series of thin sections through the head should then be made and mounted in balsam for microscopic examination.

a. In a section through the anterior end of the head, notice: —

1. The cut surfaces of the five pairs of arms (Fig. 186, *a*, *a*, *a*, *a*, *a*).

2. Near the centre of each arm a brachial ganglia (Fig. 186, *b*, *b*, *b*, *b*, *b*), which consists of a central axis of white matter or nerve fibres, surrounded by a layer of gray matter or ganglion cells, outside of which the ganglion is covered by an investing sheath.

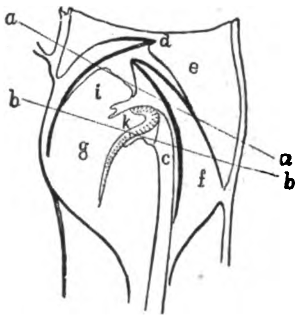

FIG. 185.

FIG. 185. — Diagram of vertical section of buccal body. (Drawn from nature by W. K. Brooks.)

a–b. The plane of the section shown in Fig. 186. *c–d*. The plane of the section shown in Fig. 187. *c*. Œsophagus. *d*. Superior or ventral mandible. *e*. Inferior or dorsal mandible. *f*. Muscles of dorsal mandible. *g*. Muscles of ventral mandible. *i*. Tongue. *k*. Radula.

3. In some of the sections, the transverse or circular commissure, which connects these ganglia with each other, will be found. Notice that the fibres of the commissure pass through the layer of gray matter into the central axis of white matter of the ganglia.

4. In the centre of the section notice a large oval body, the transverse section of the buccal mass.

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5. On the ventral edge of this is a space (Fig. 186, *c*), the mouth.

6. Dorsal to the mouth is the section of the small dorsal jaw (*d*) of the beak, which is shown in longitudinal section at (*d*), in Fig. 185.

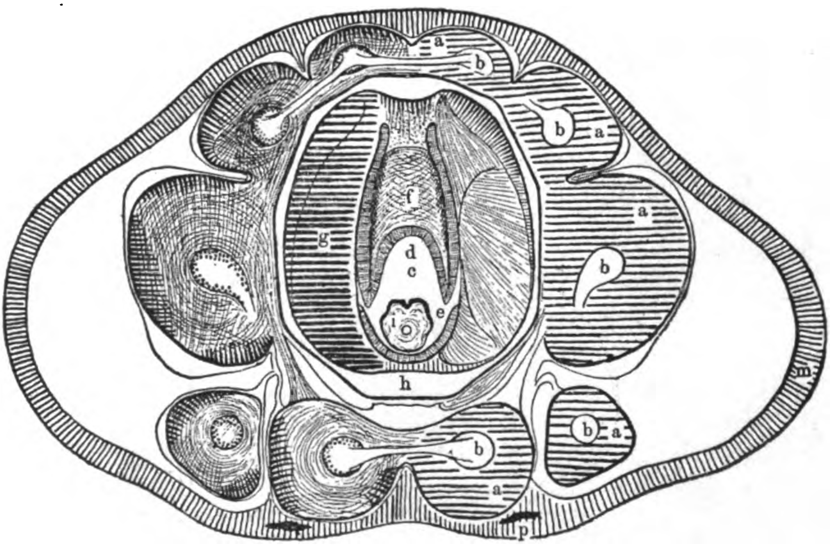

FIG. 186.

FIG. 186. — Transverse section through the anterior end of the head of a young specimen of Loligo Pealii; magnified about twenty diameters. (Drawn from nature by W. K. Brooks.) The shading in fine lines shows the course of the muscular fibres.

a, a, a, a, a. Transverse section of the arms. *b, b, b, b, b.* The brachial ganglia and commissures. *c.* Pharynx. *d.* Dorsal mandible. *e.* Ventral mandible. *f.* Muscles of dorsal mandible. *g.* Muscles of ventral mandible. *h.* Lip. *i.* Tongue.

7. Between the lateral portions of this jaw the muscle (*f*) which moves it.

8. The sides of the buccal mass are formed by the two large muscles (*g*) which move the ventral or larger mandible.

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9. This mandible is shown in section at *e*, in the ventral margin of the mouth.

10. A rounded body, the tongue (*i*), projects into the cavity of the mouth on its ventral side.

b. In a section near the middle of the buccal body (Fig. 187), notice: —

1. The commissures (*b*, *b*), which run down into the head from each of the brachial ganglia. At first these commissures lie in the axes of the arms, but in a section a little farther from the anterior end they will be found to be in the space around the buccal body.

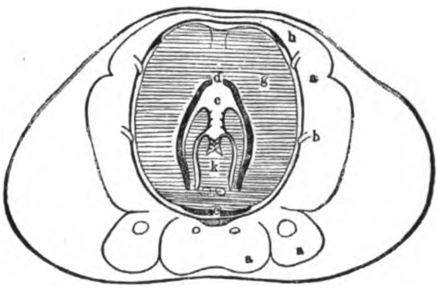

FIG. 187.

FIG. 187. — Section a little further back, less highly magnified. (Drawn from nature by W. K. Brooks.)

k. Radula. Other letters as in Fig. 186.

2. The buccal body is, at this level, almost entirely made up of the large mandibular muscles (Fig. 187, *g*).

3. In the central axis, but nearer to the dorsal than to the ventral surface, notice the pharynx (*c*).

4. Around the dorsal edge and sides of the pharynx the cut section of the dorsal mandible (*d*).

5. Projecting into the cavity of the pharynx on the ventral or siphonal side, is a muscular, tongue-like body, the *odontophore*, or the muscle of the lingual ribbon (*k*).

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(i.) On the pharyngeal or dorsal surface of this muscle notice the teeth of the lingual ribbon. This consists, 1st, of a delicate *sub-radular membrane*, which covers the surface of the muscle, and 2d, of the *radula*, or series of chitinous teeth, which project into the cavity of the pharynx. In a cross section these teeth are seen to be of two kinds, 1st, a central, symmetrical tooth, the *rachidian tooth*, which, with the rachidian teeth above and below it, forms the *rachis* of the lingual ribbon, and 2d, on each side of this a series of three *lateral teeth*.

c. In a section a little farther back notice that the cavity of the pharynx is completely separated from that of the lingual ribbon, and the outer angles of the pharynx are folded to form the superior salivary glands.

d. In a section through the eyes, notice: —

1. The small œsophagus (Fig. 188, *c*), with its epithelial lining raised to form longitudinal folds, which are seen, in cross section, as little papillæ projecting into its cavity.

2. Ventral to the œsophagus, and enclosed in a common sheath with it, the ducts of the two inferior salivary glands.

3. On the middle line of the body, between the œsophagus and the ventral surface of the head, the cross section of the heart-shaped *pedal ganglia* (Fig. 188, *d*), which consist of a central axis of white nerve fibres, and a peripheral layer of gray matter, or ganglion cells.

4. Around the periphery of the ganglion notice the nerve commissures (*e*, *f*), which pass from the arms into the ganglia. Notice that they pass through the gray layer of ganglion cells into the central white matter.

5. On the sides of the head notice the transverse sections of the eyes.

6. The eye consists of an *anterior chamber* (*m*), and a

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posterior chamber (*k*), separated from each other by the *lens* (*l*).

(i.) The anterior chamber opens in Loligo to the exterior by a small orifice (Fig. 176, *c*), situated at the anterior angle of the eye.

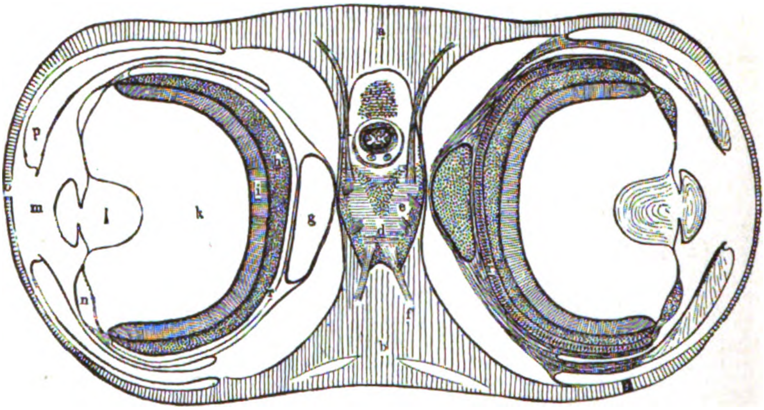

FIG. 188.

FIG. 188. — Section through the head and eyes of a young specimen of Loligo Pealii; magnified about twenty diameters. (Drawn from nature by W. K. Brooks.)

a. Dorsal muscles of head. *b.* Ventral muscles of head. *c.* Œsophagus and salivary ducts. *d.* Pedal ganglion. *e.* Nerve commissures to brachial ganglia. *f.* Nerves to muscles of head. *g.* Optic ganglion. *h.* Ganglionic layer of retina. *i.* Layer of rods of retina. *k.* Posterior chamber. *l.* Lens. *m.* Pupil. *n.* Ciliary ganglion. *o.* Cornea. *p.* Iris. *r.* Cartilaginous capsule of eye.

(ii.) The outer wall of the anterior chamber, in Loligo, is formed by a transparent cornea (Fig. 188, *o*), which is part of the general integument of the body. In Ommastrephes the cornea is represented by two movable lids, and the anterior chamber opens directly into the water.

(iii.) Inside the cornea a circular fold (*p*) runs forwards over the ball of the eye, to form the iris, which surrounds

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a central opening, the pupil (m). The posterior surface of the iris is covered with a layer of epithelial cells, filled with black pigment.

(iv.) The lens (l) lies behind the pupil, and separates the anterior chamber from the posterior. It is divided by a deep equatorial groove into a small anterior portion, which projects into the anterior chamber, and a much larger portion, which lies in the posterior chamber. It is held in place by the ciliary body (n), which runs into the groove between the two divisions of the lens.

(v.) The ciliary body is thin near the centre of the eye, but peripherally it becomes thick, and contains a ciliary ganglion (n), which consists of large granular nucleated ganglion cells. The posterior or internal surface of the ciliary body is covered by a layer of black pigment.

(vi.) The posterior chamber (k) is filled, in the living animal, by the transparent *vitreous humor*, but in preserved specimens the vitreous humor is somewhat opaque, finely granular, and shrunken, filling only a small part of the chamber.

(vii.) The sides and back of the posterior chamber are formed by the *retina* (Fig. 188, h, i). This is of nearly uniform thickness, and it ends abruptly around the anterior edge, where it joins the ciliary body. It consists of three layers.

(viii.) The inner layer (i) will be seen to be marked by fine parallel striations, perpendicular to the surface of the eyeball. Examination with higher power will show that this striation is produced by fine lines of black pigment, which run inwards to the posterior chamber. Between the lines of pigment are the transparent *rods*, which compose the greater part of this layer. On the surface of the posterior chamber the ends of the rods are covered by a delicate layer of black pigment.

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(ix.) The outer layer (*h*) of the retina is about as thick as the layer of rods, and is made up almost entirely of ganglion cells, and is similar, in structure, to the surface layer of the pedal ganglion (*d*).

(x.) The inner layer of rods is separated from the outer layer of ganglion cells by a thin third layer, the layer of pigment. This is continuous at the anterior edge of the retina with the layer of pigment on the internal surface of the ciliary body.

(xi.) Outside the retina there is a layer (*r*) of cartilage and muscular fibres, which supports the retina.

(xii.) Outside this is the optic ganglion (*g*). In the more anterior sections this ganglion is small, and consists almost entirely of gray matter, but in sections farther down the head it is very large, and consists, like the pedal ganglion, of an outer layer of gray ganglion cells, and a central axis of white nerve-fibres, some of which pass through openings in the cartilaginous eye-capsule (*r*) into the ganglionic layer of the retina.

e. In a section just posterior to the eyes (Fig. 189) notice the œsophagus (*l*), surrounded by a sheath of circular fibres, which also enclose the ducts of the salivary glands.

1. Dorsal to this the middle line of the body is occupied by the *cerebral ganglia* (*m*), and the commissure (*g*) between the optic ganglia.

2. The sides of the head are filled by two great masses,— the optic ganglia (*h*). Each of these consists of a surface-layer of gray ganglion cells (*j*), of a second thin layer of white matter (*i*), and of a great central mass of white matter (*h*) in which are complicated radiating bands of ganglion cells.

3. On the ventral surface of the œsophagus, on the middle line of the head, the *pedal* ganglion (*f*).

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4. Outside the brain and inside the integument of the head notice the cut surfaces of the upturned edges of the *head cartilage* (*e*, *k*).

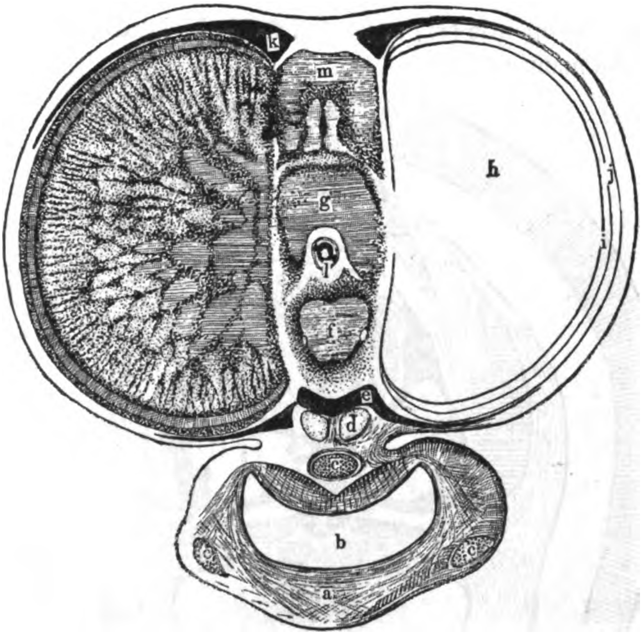

FIG. 189.

FIG. 189. — Transverse section through the head of a young specimen of Loligo Pealii; magnified about twenty diameters. (Drawn from nature by W. K. Brooks.)

a. Circular muscles of siphon. *b*. Cavity of siphon. *c*. Longitudinal muscles of siphon. *d*. Venæ cavæ. *f*. Pedal ganglion. *g*. Optic commissure. *h*. Optic ganglion. *i*. Peripheral layer of white matter. *j*. Peripheral layer of gray matter. *l*. Œsophagus. *m*. Cerebral ganglion. *e*, *k*. Cephalic cartilage.

5. On the ventral surface of the head notice the section of the upper end of the siphon (*b*), the wall of which consists of longitudinal muscles (*c*, *c*, *c*) and circular muscular fibres (*a*).

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6. Between the siphon and the brain the cut sections of the anterior venæ cavæ (*d*).

f. In a section through the base of the head (Fig. 190) notice: —

1. The mantle (*m*) separated from the head and siphon by the mantle-cavity.

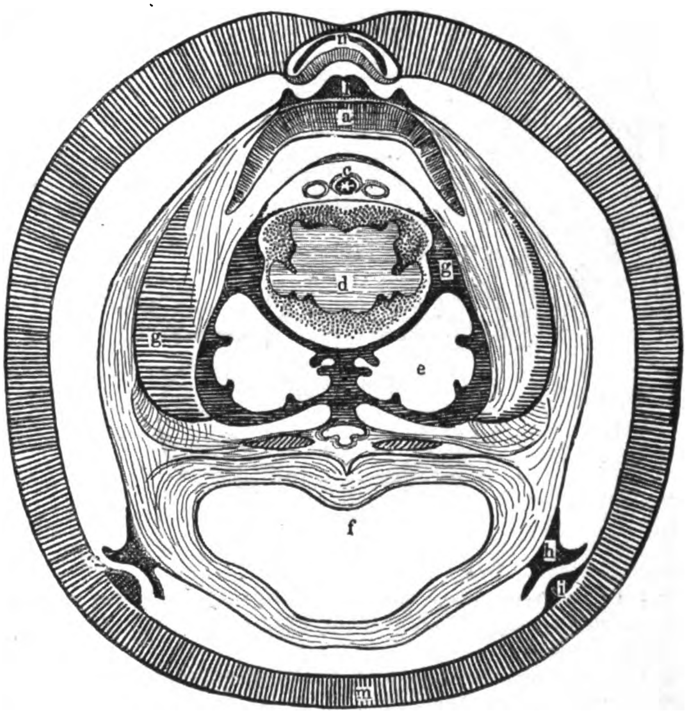

FIG. 190.

FIG. 190. — Transverse section through base of head of young specimen of Loligo Pealii; magnified twenty diameters. (Drawn from nature by W. K. Brooks.)

a. Retractor muscle of head. *c*. Œsophagus. *d*. Visceral ganglion. *e*. Ear capsule. *f*. Siphon. *g*. Cephalic cartilage. *h*. Siphonal cartilage. *i*. Mantle cartilage. *l*. Neck cartilage. *m*. Mantle. *n*. Pen and pen sac.

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2. On the dorsal median line, the upper end of the pen (n) in its sac.

3. Opposite this, on the dorsal surface of the head, the neck cartilage (l).

4. Ventral to this the retractor muscle of the head (a). On the middle line, near the dorsal surface of the head, the œsophagus (c), with a salivary duct on each side of it.

5. Ventral to the œsophagus the cross section of the visceral ganglion (d), which consists of a central axis of white matter, and a thick peripheral layer of gray matter.

6. Around the œsophagus and visceral ganglion the *cephalic cartilage* (g, g), which differs in form in different sections. It forms a concave tray or box, which supports the brain, and folds up around it at its edges.

7. Ventrally to the visceral ganglion the ear-capsule (e), — a large hollow with vertical ridges of cartilage projecting into it from the sides. In a favorable section the ear-capsule will be seen to contain a second capsule of large ciliated cells, outside which are scattered ganglion cells. In a section through the anterior edge of the ear-capsule the auditory nerve may be seen to pass from the visceral ganglion into the ridge on the dorsal surface of the capsule.

Other sections may show the nerves which pass from the visceral ganglion to the siphon, and to the ganglia stellata.

8. On the ventral median line between the ears and the siphon, notice the single anterior vena cava, which has been formed by the union of the two which are found in more anterior sections.

9. Notice the cross section of the siphon, with its two cartilages (h) fitting around the cartilaginous ridges (i) on the inside of the mantle.

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XXX.—THE DEVELOPMENT OF THE SQUID.

(*Loligo Pealii.*)

THE eggs of the sea-urchin present an illustration of total regular segmentation; and those of a lamellibranch illustrate total irregular segmentation. The eggs of the squid may be examined as examples of partial segmentation.

The eggs of the common squid are frequently taken in the trawl or dredge, and they are often found among the contents of a seine which has been drawn over a weedy bottom. They are also found occasionally on the beach, among the sea-weeds which have been washed ashore. They are contained in a cluster of elongated, spindle-shaped, transparent egg-capsules, each of which contains from twenty to seventy or eighty eggs. The capsules are all joined to a central stem, thus forming a cluster, something like a bunch of grapes, and six or eight inches long. Freshly-deposited eggs are not found as frequently as partially-developed ones, and in the latter the little squid can readily be seen, moving about within the egg-shell.

The newly-laid egg is surrounded by a transparent, elastic, oval egg-shell (Fig. 191, *a*), with an opening, the micropyle, *m*, at one end. Outside the egg-shell is the gelatinous substance of the capsule, and inside, the elongated oval yolk floats, suspended in a transparent albuminous fluid. At first sight the yolk appears to be homogeneous, but careful examination shows that it is filled with oil drops of various sizes, and with faintly marked edges.

Before the egg is laid the end of the yolk nearest the micropyle becomes different from the rest. Its oil drops disappear, it becomes transparent, finely granular, and

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forms the *germinative area* of the egg, a little protoplasmic cup, which rests upon one end of the large yolk. In a few hours the process of segmentation divides this cup up into a layer of cells, the *blastoderm* (Fig. 191, *c*). It is rather difficult to find the early stages of segmentation, but the process is as follows: a groove or furrow makes its appearance on the surface of the germinative area, and divides it into halves. A second furrow, at right angles to the first, then divides it into quarters, and two more into eighths, and so on, until it is divided up into a number of wedge-shaped cells, with their pointed ends meeting at the centre, and their broad ends at the periphery of the germinative area. The tips of the central ends are then segmented off, as a central ring of small cells, another ring is formed outside the first, and so on, and the cells which are thus formed are also divided up into smaller ones. In this way the germinative area is cut up into a layer of blastoderm cells, as shown in Fig. 191, with the bases of the wedge-shaped cells, or *segmentation pyramids* around its edge.

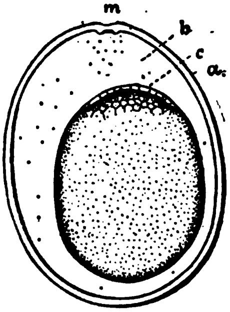

FIG. 191.

FIG. 191. — An egg in which the process of segmentation is somewhat advanced. (Drawn from nature by W. K. Brooks.)

a. Egg-shell. *b*. Space between the shell and the yolk, filled with transparent albumen. *c*. Cap of segmentation spherules. *m*. Micropyle.

The cells of the blastoderm are not very well marked in a living egg, but when treated with borate of carmine, to which a very small quantity of one-tenth per cent solution of osmic acid has been added, they become very conspicuous. Fig. 192 represents the edge of the blastoderm

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of the egg shown in Fig. 191, after it has been thus treated. The centre of the germinal area is occupied by a number of small spherules which are irregularly spherical, and each of which contains a very large nucleus.

As we pass from the centre of the cap towards the periphery, the spherules become larger, and at its growing edge they are replaced by large flattened pyramids (*b*, *b*), which radiate out on all sides, upon the surface of the yolk (*a*), and gradually pass into the surface of the yolk, without any distinct boundary at their outer ends.

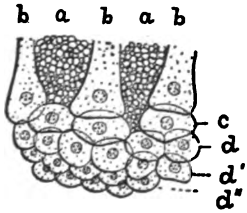

FIG. 192.

FIG. 192. — More highly magnified view of the growing edge of the blastoderm of the egg shown in Fig. 191, after staining with osmic acid and borate of carmine. (Drawn from nature by W. K. Brooks.)

a. Unsegmented yolk. *b*. Segmentation pyramids. *c*. First row of cells, which have been formed by separation from the ends of the pyramids. *d*. Second set of cells, which have been formed by the division of cells like *c*. *d'*. Third set, similar to *d*. *d''*. Fourth set, similar to *d* and *d'*.

Careful examination shows that the segmentation spherules are pretty regularly arranged with reference to these pyramids. Just inside the broad inner ends of the pyramids, there is a ring of large spherules (*c*), equal in number to the pyramids, and presenting every indication of having been just formed by the separation of the proximal end of each pyramid from the larger distal portion. Inside these there is a second ring of spherules (*d'*), about half as large, and exactly twice as numerous as the first set, and so placed that a pair of the spherules of the second set are pretty nearly in a straight line with one of the first set and the base of a pyramid. Each pair of this

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set is obviously the product of the division into two of a spherule like those of the set (c), formed by separation, somewhat earlier, from the end of a pyramid. Inside this set is another series (d''), equal in number to the set (d'), and arranged like this set, in pairs along the radii which end in the pyramids. Inside there is another set (d'''), of the same kind, so that, as we pass inwards in the line of each pyramid continued, we have the following series: 1. the pyramids; 2. one large spherule (c); 3. two spherules (d'); 4. two spherules (d''); 5. two spherules (d'''), and so on.

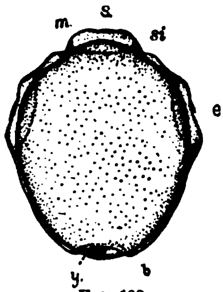

FIG. 193.

FIG. 193. — View of the anterior surface of an embryo about two days old. (Drawn from nature by W. K. Brooks.)
m. Mantle. *s.* Shell area. *si'.* Lateral siphon folds. *e.* Eye. *y.* Yolk. *b.* Growing edge of blastoderm.

In about two days the embryo is in the stage shown in Fig. 193, and the positions of many of the organs of the future squid are now indicated. The blastoderm has grown down around the yolk, which is now entirely covered by it, except at the point (y), opposite the point where segmentation began. The growing edge of the blastoderm is marked by a ridge (b), which is ciliated. The embryo is now bilaterally symmetrical, with reference to a plane through the long axis, and the blastoderm has become raised into a circular area, the *mantle* (m), at the end where segmentation began. In an anterior view (Fig. 193), there is an elevated pad, the eye-stalk (e) on each side of the body, and when one of these is seen in surface view, a little pit, or invagination in its centre, will be seen; this is the chamber of the eye. Between the eye

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and the mantle there is a little ridge (*si*), the inner siphon fold.

In a day or so more the mantle (Fig. 194, *m*) is sharply defined, and begins to overhang the mantle-cavity, under which the rudimentary gills (*g*) have appeared as little papillæ covered with cilia. They are very similar in structure to the embryonic gill-tentacles of a lamellibranch. In the centre of the mantle there is a small pit, the shell-gland (*s*), in which the shell or pen soon appears, as a little flat, transparent, circular plate (Fig. 195, *s*).

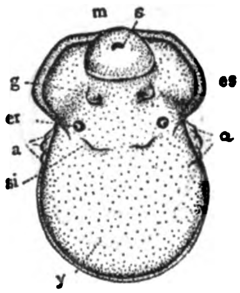

FIG. 194.

FIG. 194. — Foreshortened dorsal view of the posterior surface of the embryo shown in Fig. 193. (Drawn from nature by W. K. Brooks.)

y, *s*, and *m*. as in the preceding figure. *es*. Eye-stalk. *g*. Gills. *er*. Otocysts. *si*. Inner siphon-folds. *a*. Arms.

The eye-stalks (Figs. 194 and 195, *es*) now project considerably from the sides of the dorsal end of the body. The eye invaginations are well developed, and their openings have begun to close up, to form the pupils, in which the lenses are soon developed. In Fig. 195 the left eye is shown in surface view and the right in profile. The lateral siphon-folds (*si'*) are well developed, and the two internal siphon-folds (Fig. 194, *si*) have appeared on the posterior surface of the body. Opposite the outer ends of the inner siphon-folds the ears (*er*) are now present as two spherical pits, with wide mouths. On the anterior surface, the mouth (Fig. 195, *mo*) is now visible, and a short œsophagus runs inwards and upwards from it towards the dorsal surface, but soon ends blindly. On each side

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of the mouth there is a very faintly-marked undulating line of cilia, the velum (*v*).

Three pairs of rudimentary arms (*a*) are now present upon the sides of the body, about half-way between the mantle and the opposite pole of the egg. The yolk is now entirely surrounded by the blastoderm, and has departed still further from the regularly curved shape of Fig. 191. The prolongations into the mantle and the eye-stalks are well defined, and the portion of the yolk contained within

FIG. 195. — Embryo a little older than the one shown in Fig. 193, represented with its dorsal surface above, and showing the anterior surface of the body, as seen from the left side. (Drawn from nature by W. K. Brooks.)

The letters of reference have the following significance in all the figures which follow: —

a. Arms. *a'*. Posterior or siphonal pair of arms. *a''*. Second pair. *a'''*. Third pair. *e*. Eyes. *er*. Otocyst. *es*. Eye-stalk. *f*. Fins. *g*. Gills. *h*. Branchial hearts. *m*. Mantle. *mo*. Mouth. *re*. Rectum. *si*. Inner siphon-folds. *si'*. Lateral siphon-folds. *sm*. Siphonal muscle. *v*. Velum. *y*. Yolk. *y'*. External yolk-sac. *y''*. Yolk mass of the eye-stalks and head. *y'''* and *y''''*. Yolk masses of the body and mantle.

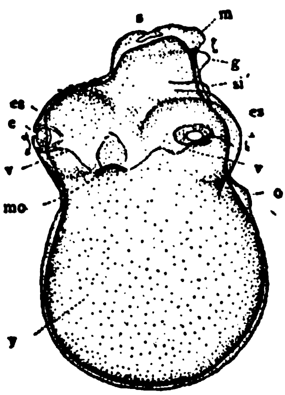

FIG. 195.

the body of the embryo, which is not quite half the whole, is separated by a well-marked constriction, just dorsal to the arms from the remainder, which is now nearly spherical. The thin layer of blastoderm which covers this external portion of the yolk is split into two layers, separated from each other by a cavity which is largest along the median plane of the body, and which is traversed by a few branched corpuscles, by the contraction of which,

rhythmical waves of the outer layer are set in motion on the surface of the yolk. The fact that the mouth is dorsal to the row of arms at this period is worthy of notice.

The next figure (Fig. 196) is a view of the posterior surface of a somewhat older embryo, represented, with its dorsal surface below. The mantle (*m*) now overhangs the body considerably at the sides, as well as posteriorly, and the portion of the yolk which projects into it is more sharply marked off than before, and is drawn out to a point at the dorsal end. The eye-stalks (*es*) and their yolk protuberances, are much more prominent, and the constriction which separates the body from the external yolk is much more marked. The three pairs of arms are a little larger than before, and a cavity is visible in each of them. The inner siphon-folds (*si*) have lengthened, and their outer ends now point towards the outer folds (*si'*), from which, however, they are still widely separated. The most important differences between this and the preceding stage are differences of proportion and relative size, which are sufficiently well shown in the drawings, and do not call for description.

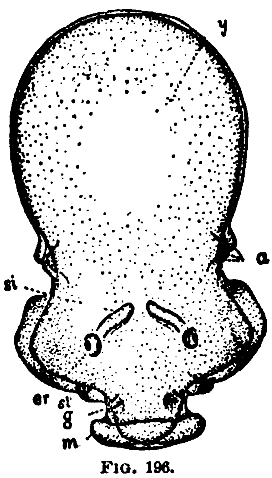

FIG. 196.

FIG. 196.—The posterior aspect of an older embryo, with its dorsal surface below. (Drawn from nature by W. K. Brooks.) For explanation of letters see Fig. 195.

Fig. 197 is a posterior view of an older embryo, figured with its dorsal surface below instead of above, in order to

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facilitate comparison with the figures which follow, and with the adult animal. The mantle (*m*) has extended its edge sufficiently to form a very well defined mantle-cavity, within which the bases of the gill tentacles (*g*) are now contained. The tail fins (*f*) have made their appearance upon the dorsal surface of the mantle, and the rectum (*re*) is now present as a raised, longitudinal, hollow rod, upon the median line of the posterior surface between the gills. The two inner siphon-folds (*si*) have met upon the middle of the body, and their free edges have bent towards each other to form the opening of the siphon; but they have not yet united with each other, and the siphon has the characteristics of that of the adult Nautilus. The inner folds are still separated from the outer ones (*si'*), but the latter have begun to bend around upon the posterior surface of the body. The eye-stalks (*es*) are now extremely prominent and conspicuous, and the yolk protuberances no longer entirely fill them, but have begun to decrease in size, thus leaving between the eye and the yolk a space in which the optic ganglion has made its appearance.

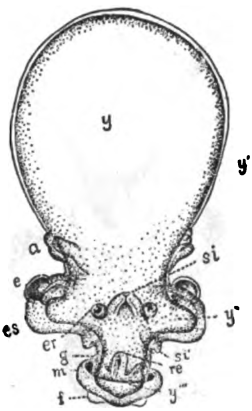

FIG. 197.

FIG. 197. — A similar view of an older embryo, with its dorsal surface below. (Drawn from nature by W. K. Brooks.)
For explanation of letters see Fig. 195.

The three pairs of arms (*a*) are much elongated, and begin to bend away from the surface of the yolk, which is now divided into three well-marked regions: the external yolk (*y'*), the portion within the head-region and eye-

stalks (y''), and the portion within the body and mantle (y'''). During its development the embryo has undergone an increase in size, and although the drawing is less enlarged, the embryo shown in Fig. 197 is actually much larger than that shown in Fig. 194. The external yolk-sac shares in this growth, and is very much larger at a somewhat later stage than the whole egg was at the beginning of the process of development.

Fig. 198 is a view of the posterior surface of an embryo somewhat older than in Fig. 197. The external yolk-sac (y) has grown so much larger that only a small part of it is shown in this and the next three figures. The mantle (m), has grown so much that the gills (g), and the rectum are nearly contained in the mantle-cavity. A constriction across the base of each gill has separated the branchial heart (h), from the gill proper. The inner folds (si) of the siphon, have united with each other to form the closed siphon tube, and the inner and outer folds (si, si'), have met and are uniting with each other.

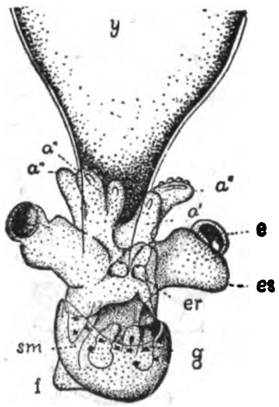

FIG. 198.

FIG. 198. — The posterior surface of an older embryo, as seen from the right side, with the dorsal surface below. (Drawn from nature by W. K. Brooks.)

For explanation of letters see Fig. 195.

The walls of the otocysts, (er), have grown thin, and their cavities have greatly enlarged; the otoliths have made their appearance, and the two chambers have begun to move towards the median line, under the end of the siphon.

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The external openings of the otocysts have become constricted to long, tortuous, ciliated ducts, which are not visible with a low power, and are not shown in the figure.

The eye-stalks, (*es*), are of about the same relative length as in the last figure, but the yolk prominences which have filled them up to this time are now almost entirely withdrawn or assimilated, and the cavity of the eye-stalk is nearly filled by the ball of the eye (*e*), the optic ganglion, and the white body.

The arms have lengthened, and suckers have appeared upon the longest pair (a''), and a new pair (a'), have made their appearance upon the posterior or siphonal surface of the body.

The yolk is now divided into four well-marked regions, the external yolk sac (y'), which is still nearly spherical; the head yolk, which is pretty nearly cylindrical, and which passes gradually into the external yolk sac; the body-yolk, much smaller than the head-yolk, and separated from it abruptly by a well-marked change of outline; and the little mass of yolk, at the dorsal end of the body, constricted off from the mass by a deep groove.

Fig. 199 represents a view of the posterior surface of a somewhat older embryo.

The mantle is now large and bowl-shaped, and covers the greater part of the body dorsal to the eye-stalks. Chromatophores now begin to make their appearance around the posterior side of the edge of the mantle, and those which first appear are of a dark brown color.

The gills (*g*), have lengthened considerably, and are divided by constrictions into a series of enlargements, the dorsal one being much larger than the others, and becoming the branchial heart. The inner and lateral folds

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of the siphon have completely united with each other, and at the point of union the siphon is also united to the body wall, and the retractor muscle of the siphon (Fig. 198, *sm*), now runs back to unite with the inner anterior surface of the mantle. The otocysts have almost met each other upon the median line, under the siphon, and their walls are now very thin. The eye-stalks are prominent at this stage, but they soon begin to disappear.

FIG. 199.

The embryo shown, from the right side, in the next figure (Fig. 200), has assumed the general form of the adult, and the eye-stalks have almost disappeared, although, as shown in a posterior view (Fig. 201), the eyes are very prominent still, and are directed more towards the ventral surface than they are in the adult.

FIG. 199. — Posterior surface of a somewhat older embryo. (Drawn from nature by W. K. Brooks.)
e. Eye. *i*. Ink bag. *r*. Rectum. The other letters as in Fig. 195.

The mantle now covers about one-half the entire length of the embryo, exclusive of the yolk-sac, and the neck-cartilage (*nc*), has made its appearance, forming a support for the edge of the mantle, on the middle line of the anterior surface of the head. The posterior surface of the mantle is now pretty well covered with chromatophores, which at this stage possess remarkable power of expansion and contraction, and render the living embryo a very beautiful and wonderful sight under a low magnifying

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power. They are, as yet, entirely absent from the anterior surface of the mantle.

About this time small polygonal areolations, much like epithelial cells, begin to make their appearance on the posterior surface of the mantle, and soon spread over the whole mantle, except the middle line of the anterior surface, as shown in the figure. At a later stage (Figs. 201

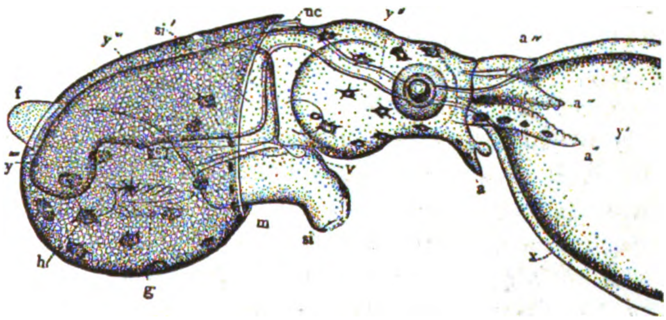

FIG. 200.

FIG. 200. — A somewhat older embryo, seen from the right side. The external yolk is now so large that only part of it is shown in the figure. (Drawn from nature by W. K. Brooks.)

a', *a''*, *a'''*, *a''''*. The four arms of the right side. *f*. The fin. *g*. The gill. *h*. The branchial heart. *m*. The free edge of the mantle. *nc*. The neck cartilage. *si*. The siphon-tube. *si'*. The lateral chamber of the siphon. *v*. The valve of the siphon. *x*. The space between the integument and the surface of the external yolk. *y'*, *y''*, *y'''*, *y''''*. The four divisions or regions of the yolk.

and 202), they cover the head and arms, as well as the mantle, and still later they make their appearance upon the surface of the siphon.

Upon cursory examination, they resemble epithelial cells so much that they might readily be mistaken for them; but when more carefully examined with a high power,

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they are seen to be due to the presence of minute branching tubes, which, spreading over the surface of the body and inosculating, divide it up into small polygonal areas.

No fluid can be seen to circulate in them, but as they appear at about the same time with the larger blood-vessels of the surface of the body, they are probably the indications of a system of capillary vessels.

The course of the larger blood-vessels on the posterior face of the mantle is shown, at a somewhat later stage, in Fig. 201. A large vessel will be seen to enter the mantle on the median line near the dorsal end of the body. This is the pallial artery from the systemic heart. Passing forwards, it divides into three branches; a pair of large ones, and a median unpaired smaller one. The latter runs forward, nearly to the lower edge of the mantle, and divides up into a number of smaller branches. The two larger branches diverge, and running out towards the free edge of the mantle, give rise, on their inner edges, to a number of irregular branches, and on their outer edges, to a number of nearly parallel trunks, which communicate with a pair of large venous trunks, each of which receives a smaller trunk from the median tract of the mantle, and then, bending around the side of the body, runs inwards to open into the larger *vena cava*, from which the blood passes into the branchial heart, and is conveyed to the gills. The branchial hearts appear at quite an early stage of development, but the systemic heart is not developed until about the stage shown in Fig. 201. During the later stages of development, and in the adult also, the small size of the gills is no doubt compensated, to a great degree, by the aeration of the blood while it is passing through the system of vessels near the exposed surface of the mantle.

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At the stage shown in Fig. 200, the siphon has substantially its adult form, and is made up of two lateral chambers (*si'*), which have been formed from the lateral siphon folds, and which open into the mantle-chamber, but have no external openings; and a single median chamber (*si*), on the posterior surface of the body, which has been formed by the union of the two inner siphon folds, and which opens into the mantle-chamber as well as externally.

At the point where the lateral chambers meet the median chamber, the wall of the siphon is united to the wall of the body, and the three chambers are thus shut off from communication with each other.

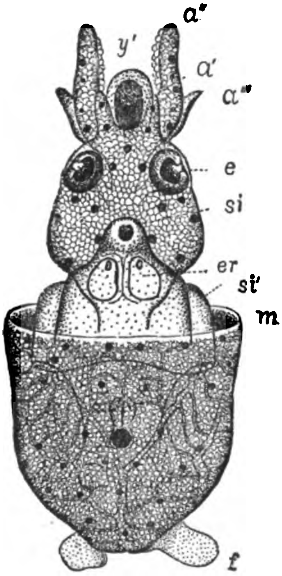

FIG. 201.

FIG. 201. — A free swimming squid, with the external yolk almost absorbed. (Drawn from nature by W. K. Brooks.)
The letters as in the preceding figures.

The animal is so perfectly transparent that the valve-like action of the two outer chambers can be perfectly seen, as their free inner edges are thrown out against the mantle so as to close it at each contraction, and the water, which passes in around the whole free edge of the mantle, is thus concentrated in the funnel-shaped middle chamber of the siphon.

At about this time the valve of the siphon (Fig. 200, *v*), is developed as a single unpaired flap, which arises from the posterior surface of the neck.

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Considerable change has now taken place in the shape of that portion of the yolk which is contained in the head. It is reduced to a long, narrow tube (y''), which connects the portions contained in the body proper (y''', y''''), with the external yolk sac (y'). The pulsatile space (x), between the outer wall and the surface of the yolk sac, is more plainly shown in this figure than in the preceding ones, although a profile view shows it with equal distinctness at earlier stages.

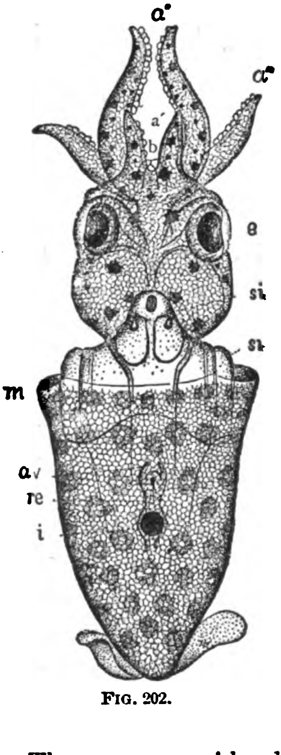

FIG. 202.

Fig. 202 is a posterior view of an embryo a little older than the one shown in Fig. 201. A large rounded prominence on each side of the head marks the position of the eye-stalk, and the eyes are farther forward than they are in older specimens, but in other respects the form is very similar to that of the adult. The ink sac (i) has appeared, and is filled with ink, and the tip of the free portion of the rectum is prolonged at its corners into the pair of ear-like anal valves.

FIG. 202. — A free swimming squid, with the external yolk entirely absorbed. (Drawn from nature by W. K. Brooks.)

The letters as in the preceding figures.

There are considerable individual variations in the arrangement of the chromatophores, but there are certain

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features which are observed in all the specimens, and which seem to be constant.

The first which make their appearance are dark brown in color, and are placed in a ring of six or seven, (Fig. 202), around the edge of the mantle on the posterior surface. They are a little smaller, and somewhat more excitable than those which appear subsequently, and they can be readily recognized in the later stages shown in Figs. 201 and 202. They are soon followed by larger spots of the same dark brown color, scattered irregularly over the posterior surface of the mantle (Fig. 202).

The next spots to appear are upon the arms, and are also dark brown. At first there are two upon the first or siphonal pair of arms, and three upon the second pair (Fig. 199). A fourth soon appears upon the second arm, and these four remain conspicuous until quite a late stage of development (Fig. 202). Three large brown spots now appear upon the posterior surface of the head (Fig. 199), and they are soon followed by others.

A second set of spots, more deep-seated and of a bright orange color, soon make their appearance, and are much more constant in position than the brown ones. The first pair which appear are just in front of, or ventral to the eyes. They are soon followed by a single one on the middle line of the head, at the bases of the first pair of arms, and another single one on the middle line of the edge of the mantle. About the same time a pair appear dorsally to the eyes, and another pair on the edge of the mantle, near the sides.

Four small orange spots next appear upon the second pair of arms (Fig. 202, a''), alternating with the four

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larger brown spots, and, soon after, a ring of six or eight orange spots appears on the mantle, dorsal to the ink bag. Two orange spots next appear upon the first pair of arms (Fig. 202, *a′*), alternating with the brown spots.

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